TRANSACTIONS AND PROCEEDINGS

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SESSION LXI.

ADDRESS DELIVERED AT THE OPENING OF THE SESSION BY Professor A. P. AITKEN, M.A., D.Sc., President of the Society.—12th November 1896.

THE NITROGENOUS FOOD OF PLANTS.

In the year 1674 a very remarkable discovery was made by John Mayow, viz. that the air, which from all time had been regarded as an elementary substance, was really a mixture of at least two gases—one of them was a gas which enabled things to burn, and the other was one that did not. Moreover, he found that the gas which enabled things to burn, or which "supported combustion," as it is commonly expressed, was also the gas that enabled animals to breathe or that supported respiration, and that the other did not. He carried his researches even further, and found that this active gas, which he called the "nitrous spirit of the atmosphere," took part in the making of acids, though it was not sour itself, and also that it was contained in large quantity in nitre or saltpetre. Strange to say that discovery seemed to create no interest at the time, the story of it was told to listless ears and it fell into oblivion.

Exactly one hundred years later (1774) that same nitrous spirit of the air was discovered by Priestley, who called it "dephlogisticated air," and it was thereafter described by Lavoisier, who called it "oxygen" or the acid maker. The other constituent had been discovered by Rutherford in the Botanic Garden of Edinburgh in 1742, and shown to be a gas that animals could not live in, and he called it "mephitic air." I do not know how it was that Professor Rutherford was led to make the experiment that resulted in this discovery, but it was a very satisfactory experiment,

made with very simple apparatus, viz. a bell jar, a basin and some lime-water, and a few mice. He put the lime-water in the basin and inverted over it the bell jar. Under the bell jar he slipped a mouse and watched its behaviour. When it began to show signs of distress he pulled it out by means of a string tied to its tail and slipped in another in its place. The second mouse showed signs of distress much sooner than its predecessor, and another mouse was substituted, who succumbed in a still shorter time. On continuing the experiment it was found that the air under the bell jar had grown smaller in bulk, and that it was of a kind that a mouse could not endure with comfort for a moment. This was the second great constituent of the atmosphere, to which Lavoisier in after years gave the name of *Azote*, to signify that it was a gas in which animals could not live. For the same reason the Germans call it *stickstoff* or choking stuff, while we in this country call it *nitrogen*, which means the nitre maker, for it is found in nitre as a very characteristic constituent along with oxygen—the nitrous spirit of Mayow. Later researches showed that this gas, nitrogen, in which an animal could not breathe and a candle could not burn, occupied about four-fifths of the entire atmosphere, the remaining fifth being oxygen.

The properties of nitrogen were studied by many chemists, but it was found to be a very uninteresting subject. It formed very few compounds, and its disinclination to unite with other elements earned for it the name of the chemical bachelor. It was found to be an idle, inert kind of a loafer, good for nothing but to get in the road of the molecules of oxygen and interfere with their oxidising work, for before a molecule of oxygen could get at anything to burn it, it must needs knock four molecules of nitrogen out of its way and heat them up into the bargain, thereby greatly diminishing the energy of combustion all over the globe. It was found, however, that when nitrogen did get into combination with other elements it could form very powerful and important substances such as ammonia, its compound with hydrogen, and nitric acid, its compound with oxygen.

Besides these two gases, there were found in the air others in small quantity but of immense importance, water

vapour usually forming less than one but often more than two per cent. of the air, and carbonic acid present to the extent of about three or four parts in ten thousand. Still more elaborate analyses have shown that ammonia is in the air to the amount of one part per million, or less, and that traces of nitric acid are also sometimes to be found.

The relation of these gases to plant life very soon began to be noticed, speculated about, and experimentally investigated.

Priestley, the year before he discovered oxygen, had, with the watchful eye of genius, made a very interesting observation. He found that air which had been "depraved," as he called it, by burning a lamp in it, or by breathing in it, could be restored to its former purity by putting a growing plant in it and exposing it to the sunlight.

The explanation of that curious circumstance did not come till a good while later. Indeed, it was not till the beginning of this century that botanists were assured that plants with green leaves took their carbon from the carbonic acid of the air, and gave out a corresponding quantity of oxygen, and that one of the great functions of plant life was the restoration to the atmosphere of the oxygen of which it had been bereft in the universal processes of respiration and combustion.

Familiar as we are with that fact at the present day, it never ceases, and never can cease, to be a subject of great interest and continual wonder that the green vegetation that clothes the globe, from the tiniest alga to the greatest forest tree, derives the half of the dry matter of which it is composed, viz. its carbon, from the carbonic acid of the air, although that gas is present in the atmosphere only to the limited extent above mentioned. It was found that this formative process, which is called *assimilation*, went on only in daylight, and most vigorously in sunshine. During the night or in the dark, plants were found to give out only carbonic acid, and further investigation showed that plants were constantly giving out carbonic acid both by night and by day in common with all other organised beings, whether vegetable or animal, and that act is known as *respiration*. Every living thing must breathe; it must take in oxygen to burn up its waste carbonaceous matter, and give it out as carbonic acid.

The quantity of oxygen that is used up, and the corresponding quantity of carbonic acid that is given out by such a torpid creature as a plant during the night, is very small, and is more than compensated by the reverse process which takes place during half an hour's sunshine in the morning. Although it is about a hundred years since the main fact concerning the process of assimilation was known —what may be called the upshot of the process—we are yet very far from knowing how it is that plants take their carbon from carbonic acid gas and convert it into their own tissues. We can see the formation of starch in the chlorophyll cells during sunshine, and its disappearance during darkness, but as yet we know nothing certain regarding the steps which lead up to the formation of starch. Whether the chlorophyll takes a formative part in the making of starch, or whether it simply acts as a screen to allow only select rays of light to reach the laboratory where the carbonic acid is being decomposed, and whether this product is hypochlorin, as Pringsheim suggests, or formic aldehyde as some have supposed, we know nothing sure. The chemistry of the carbohydrates is a very intricate subject, and difficult of exploration, and only the rudiments of it are as yet known.

If that is the case with the carbohydrates, it is so in a still more marked degree with the nitrogenous constituents of plants.

The molecule of starch is simplicity itself compared with the molecule of albumen, which may be regarded as the finished article of the nitrogenous kind that is built up in the tissues of plants. It has been estimated that the molecule of albumen may consist of from 3000 to 5000 atoms. Such estimates are mere guesses, scarce worth considering, but they serve the purpose of impressing upon the mind the extreme complexity of some of the nitrogenous substances of which plants are composed, and the enormous difficulties which that complexity places in the way of their investigation.

It is to the nitrogenous parts of plants, and especially the nitrogenous food of plants, that I wish to direct your attention for a short time; and I have been prompted to do so from the knowledge that there will be brought before

the Society during the present session some interesting information on the recent advances of a practical kind that have been made in the growth of plants, arising out of our better acquaintance with the manner in which they obtain their nitrogenous nourishment.

I have already referred to the fact that four-fifths of the atmosphere consists of free nitrogen gas. With such an enormous store of nitrogen around them it would seem, at first sight, that whatever difficulty plants might find in obtaining the other constituents of which they are composed they ought to experience no difficulty in obtaining an abundant supply of nitrogen. Practical experience, however, shows us very clearly that it is the constituent most difficult for them to obtain, as it is the most expensive for us to supply. The natural conclusion to arrive at from that consideration is that the nitrogen of the air must surely not be an available source of plant nourishment.

Up to the present decade there was no dogma more firmly rooted in the minds of botanists than this, that plants could make no use of the free nitrogen of the air. Careful experiments made by Boussingault, who was a most accurate experimenter, and whose manifold experiments may be said to have laid the foundation of agricultural chemistry, seemed to prove that plants could not assimilate free atmospheric nitrogen.

No excuse is needed to ask you to look for a minute into the details of one of his now classical experiments.

	Duration of Experiment	Number of Seeds.	Weight of Seed.	Weight of Plant.	Nitrogen in Seed.	Nitrogen in Plant.	Gain or Loss of Nitrogen.
	Months.		Gm.	Gm.	Gm.	Gm.	Gm.
Bean, nain	2	1	·780	1·87	·0349	·0340	− ·0009
,, ,,	2	1	·792	2·35	·0354	·0360	+ ·0006
,, ,,	2½	1	·665	2·80	·0298	·0277	− ·0021
,, ,,	3	1	·530	·89	·0210	·0189	− ·0021
,, ,,	3	1	·618	1·13	·0245	·0226	− ·0019
Lupine, white	1½	2	·825	1·82	·0480	·0483	+ ·0003
,, ,,	2	6	2·202	6·73	·1282	·1246	− ·0036
,, ,,	1¾	2	·600	1·95	·0349	·0339	− ·0010
,, ,,	1½	1	·343	1·05	·0200	·0204	+ ·0004
,, ,,	1½	2	·686	1·53	·0399	·0397	− ·0002
Oat	2	10	·377	·54	·0078	·0067	− ·0011
,,	2½	4	·139	·44	·0031	·0030	− ·0001
Criss	3½	3	·008	·65	·0013	·0013	·0000
,, as manure	...	10	·026				

He grew plants of various kinds in an air-tight case in soils that were composed of sand, to which he added the ashes of plants to serve as manure, but which contained no nitrogen in any form of combination. Tubes were inserted in the case through which he could water the plants with pure distilled water, and others through which air was led in after passing through sulphuric acid, to deprive it of any ammonia, and over bicarbonate of soda, to deprive it of any nitric acid. Thus no nitrogen was allowed to reach the plants but that of the free nitrogen of the air.

He weighed the seeds at the beginning, and the whole plants at the end of each experiment, and you will see from the table that the whole plant was usually only two or three times the weight of the seed itself. He estimated the nitrogen in the seeds from an analysis made of a number of others of the same kind, and, at the end, he determined the total amount of nitrogen in the plant and in the small quantity of soil it grew in. You will see that there was usually a loss of nitrogen, and in one or two cases a trifling gain.

He varied his experiments, afterwards, by giving the plant a small ascertained amount of nitrogenous manure, but the results were similar, and he felt entitled to conclude from all his experiments that plants could not assimilate the free nitrogen of the air. Coming from such a weighty authority, this view obtained general acceptance.

About the same time (1850) M. Georges Ville, Director of the Ag. Exper. Station at Joinville, Paris, was engaged in a series of experiments with a similar object in view. He had no confidence in Boussingault's experiments on account of the unnatural conditions under which he attempted to grow his plants, and he despised a crop which weighed only two or three times the weight of the seed. He also grew his plants within an air-tight case, and had complete control of the water and air supplied to them, but he gave them some nitrogenous manure, and plenty of soil and air. The result was that his plants grew to normal size, 50 or 100 times the weight of the seed they sprang from, and he found that they had assimilated free nitrogen, sometimes in a very marked degree. He grew cereals, leguminous plants, and cruciferous plants, and found that

in every case there was an assimilation of atmospheric nitrogen, but mostly in the case of leguminous plants. He published his researches, but the results were received with incredulity. They differed so totally from those of Boussingault, a distinguished member of the French Academy, that scientific men felt sure he had made some mistake, and the bitter things said against poor Georges Ville's researches rendered his life miserable. He never lost confidence, however, in the accuracy of his work, and eventually he threw down a challenge to the French Academy to appoint a committee of experts to superintend one of his experiments. The Academy took it up, and a committee of very eminent men were appointed—Dumas, Regnault, Payen, Decaisne, Peligot, and Chevreul. They superintended the experiments for several months; one important part of their supervision was to see that no nitrogenous matter was supplied to the plants in the water they were watered with. Accordingly, every time the plants were watered the residue of the water was put into a large vessel for after investigation. At the close of the experiment this water was analysed, and it was found to contain some ammonia. This staggered Ville very much, and on inquiring into the matter he found that a few days before the water was tested some of the pupils in the Museum of Natural History, where the experiment was conducted, had been making ammonia gas, which, being a penetrating gas, had very probably reached the water and been absorbed by it.

The committee were of course constrained to report that they were not satisfied that the plants had not received some ammonia from the water used in watering them. But the Academy voted Ville 2000 francs to defray the expenses of the investigation, and other 2000 to enable him to go on with it.

Thereafter two English experimenters entered the field, viz. Messrs. Lawes and Gilbert, at Rothamsted. They resolved to repeat Boussingault's experiments, but with the adoption of a number of elaborate precautions, so as to prevent any possible chance of error. The result of their investigation was to confirm the accuracy of Boussingault's conclusion, and that practically disposed of the question for

the time, but it did not silence Ville. He published a new edition of his researches in 1867. After having repeated many of his former experiments, and found them accurate, he was able, from his added experience, to see how Boussingault's method could not end in anything but failure. The plants, he maintained, could never be anything but sickly, misthriven objects under the conditions of growth he imposed on them, and he pointed out that on account of these conditions the puny plants were not allowed to arrive at that stage of development when it was possible for them to utilise the free nitrogen of the air.

In his experiments he gave the plants sufficient soil to enable their roots to grow, and he supplied them with a certain small amount of nitrate of soda, just enough to tide them over their childhood, so to speak, but not enough to pamper them and make them lazy in the vigour of their youth. He held the view that plants, like other beings of a higher type, when they found within their reach two sources of nourishment, took the one that was easiest got at; so that if a plant found nitrogenous food among its roots it absorbed that, and did not exercise its power of taking, with more difficulty, its nitrogen from the air. By careful experiment he discovered how much nitrate of soda was needed to give his plants a good start, and he stopped there, and let them find the rest of their nitrogenous food in the free nitrogen of the air he supplied to them.

So far as I can discover, no particular attention was given to Ville's further publication, and almost nobody had any confidence in his conclusions. Happening to be in Paris just twenty years ago, I paid a visit to the Experiment Station at Joinville, and knowing it was a public institution, I gave no notice of my coming. Unfortunately I did not get access to the grounds, as M. Ville was from home, but the inquiries I made regarding the work carried on there among some leading scientists in Paris were usually answered by that characteristic shrug of the shoulders with which our neighbours across the Channel are able to convey a wonderful amount of tacit information. It was quite evident that he was not regarded by the Parisian scientists as one of their set.

Seeing that the free nitrogen of the air was regarded by the highest authorities to be unavailable for plant nutrition, it became necessary to cast about and find what stores of combined nitrogen were available in the world.

I have already referred to the ammonia, which, as carbonate of ammonia, is a constant though minute constituent of the atmosphere. Its amount has been often estimated, and the estimates show extraordinary variations, from 1 part in twenty millions to as much as $3\frac{1}{2}$ parts in one million; depending on the locality where the sample of air was taken. Over the land it is more than over the sea; and it is greatest near towns where coals are being burned, and in places where organic matter is decaying. According to Angus Smith the ammonia in its rain-water over England is just about 1 part per million; in Scotland it is only half as much. In towns in England it is 5 parts on an average; in Scottish towns it is somewhat less, but in Glasgow it is 9 parts per million. It is very soluble in water, and is washed out of the air by rain. After thunderstorms there is also found nitric and nitrous acids, or their salts, in the air, and these too are washed down by rain. Rain-gauges at various observatories in Europe, notably at Rothamsted in England, have been in use for many years, to determine not only the quantity but also the quality of the rain that falls throughout the year; and the total combined nitrogen brought to the earth by them has been found to be somewhere between 4 and 10 lbs. per acre. That is a very welcome addition to the nitrogenous food of the soil; but it forms only about one-tenth of what is removed by a moderate cereal crop, and is insufficient to recoup the soil for the loss which it is constantly incurring by drainage. Always there is nitrogen in some form of combination flowing down the rivers to the sea, and the store of it on the land is being diminished. It forms an important manurial constituent for the nourishment of seaweeds, and these again are the food of fishes, many of which are brought back to the land to be consumed as food; but any such restoration goes but a very little way in making good the drain of nitrogen in some form of combination which the land is constantly suffering.

Still more serious is the loss of combined nitrogen from

the decomposition of nitrogenous compounds in a number of ways. When, in the ordinary course of nature, living things, be they animal or vegetable, fall into decay, the nitrogenous compounds they contain do not all escape into the air as ammonia, as was at one time believed. Liebig, in his famous book on "Organic Chemistry in its Application to Agriculture and Physiology," published in the middle of this century, taught that from carbonic acid gas, water, and ammonia, came the food of the world, and back to carbonic acid, water, and ammonia it all returned, either directly in its decay, or indirectly in the life and death of the animals whose frames it temporarily served to support. It was a beautiful generalisation, this cycle of change through which all organic life was held to pass; but careful investigation of the products of organic decay has shown that much of the albumen, and other nitrogenous matter contained in living organisms, is decomposed during their life, as well as at their death, into something even simpler than ammonia, viz. into the element nitrogen itself.

The proportion of the albuminoid matter reduced in this way may be very considerable, and may even amount to one-fourth of the whole of the nitrogen of the substance if conditions are favourable. Even when the nitrogenous organic matter has had its nitrogen converted into the inorganic form of nitrates, or nitrites, it is not safe; for apart altogether from the extreme ease with which these salts are washed out of the soil and into the water-courses by rain, they are, while resident in the soil, liable to be reduced in the presence of much organic matter, especially if cut off from a circulation of air; and that reduction, stopping short of ammonia, liberates their nitrogen in the uncombined state.

It has been observed that these instances of reduction are greatly hastened, if they are not entirely brought about, through the instrumentality of micro-organisms in the soil, or in any place where organic matter is accumulated. But also in the presence of air there are decompositions taking place in decaying organic matter, whereby oxidised and unoxidised products re-act upon each other and liberate the whole of their nitrogen as free nitrogen gas.

It would take me too far to enter into any detail regarding chemical processes of that kind, and it is the less necessary because, although they are known to occur, I have no idea of the extent to which they are operating, and I cannot estimate their importance.

As when organic substances are being consumed by the slow processes of putrefaction and decay, so also when they are being burned a considerable part of the nitrogen is set free as such. The burning of wood and of coal are operations in which a very appreciable amount of uncombined nitrogen is set free. It may be said of coal that its combustion is a gain rather than a loss to the available nitrogen of the world, because far more of the nitrogen it contains is set free as ammonia than as nitrogen gas. No doubt that is so, but the nitrogen contained in the coal measures must have been got from the atmosphere at the time when the plants that made the coal were growing, and we can regard the nitrogenous matter locked up in them only as part of the funded capital of the combined nitrogen of the world, and any process of combustion which sets the combined nitrogen free is an expenditure of that capital, and it is evident that if the process of spending goes on long enough, there will by and by be no capital of combined nitrogen to draw upon.

Besides the sources of loss which I have indicated as going on in what may be called dead organic matters, there are others which are known to be going on in the bodies of living animals,—fermentations in which the nitrogen contained in the albuminoid matter of their food is to some extent liberated in the uncombined form.

It will be seen that the circumstances in which combined nitrogen becomes free are very various, and as we do not know them all, but probably only a few of them, we are forced to conclude that, unless there are some means whereby free nitrogen is brought again into combination, and unless these means are not only active but abundant, we must be hastening on to a time when life in any form upon the globe must become extinct for want of nourishment.

A survey of the history of the globe shows us, however, that life is on the increase, and that organic matter is

constantly accumulating. We have only to look at the rocks of which the earth's crust is composed to be assured that at one time this planet was a molten ball on which there was no organic matter, and now it is clad in a dress of living green, and teeming everywhere with life. That vegetable and animal life should have increased so abundantly, requires that either there must at one time have been an immense store of ammonia in the atmosphere, which has gone on constantly diminishing, or there must have been, and there must be now, some process going on on a large scale whereby ammonia is being formed out of the free nitrogen of the air.

We have no reason to suppose, however, that there ever was a larger store of ammonia in the air than there is at present. The certainty is rather that at one time, viz., when the earth was at a white heat, there was no ammonia in our atmosphere at all. A red heat suffices to decompose it into its two component gases, nitrogen and hydrogen—one volume of the former and three of the latter,—and these on cooling do not again unite. It is hard to see how ammonia, if it did exist in the atmosphere at that time, could escape decomposition, and the fact that in the atmosphere there is scarcely a trace of hydrogen, and, moreover, that what little there is can be easily accounted for by volcanic action, we naturally come to the conclusion that there was no ammonia in the original atmosphere of the earth. We have therefore good reason to believe that the total amount of ammonia in the atmosphere is now not less, but probably more than it ever has been.

Seeing that there are so many ways in which combined nitrogen may be set free, and that the quantity of combined nitrogen on the globe is on the increase, there must be some process of a widespread general kind going on around us whereby the free nitrogen of the air is being brought into combination.

Despite the dictum of weighty chemical authorities that plants could not convert free into combined nitrogen, there remained many who believed that they must possess that power; for if it were not possessed by plants, there seemed to be no other direction in which to account for the ordinary conditions of organic life on the globe.

Moreover, there were some curious facts known to agriculturists that could scarcely be explained in any other way.

It was well known, from the time of the Romans, that when leguminous plants were grown on land under rotational cultivation, an abundant crop of that kind was followed the next season by a good cereal crop. They were of opinion that the leguminous crop enriched the soil.

Farmers in this country, too, have known for ages that a good crop of wheat was certain if a good crop of clover had preceded it. Now chemical analysis shows us that the clover crop is very rich in nitrogenous matter; and if we assume that this nitrogenous matter comes to the crop from the soil, it stands to reason that the removal of a clover crop should leave the soil poorer in nitrogenous matter than before. Such, however, is not the case. Chemical analysis shows that the soil is richer in nitrogenous matter after the clover crop has been carried away; so that either the roots of the clover left in the ground must have got their nitrogen from deep down in the ground, or it must have come to the plant from the air and have been stored up to some extent in the roots.

Another common observation was that when a crop of *maslum* was grown, which is a mixture of beans and oats, or when tares and oats are grown together, the oat plants are stronger and taller than those on any part of the field where the oats have grown separately. So also it is commonly observed that in pastures the places where clover is most abundant are the places where the grasses are growing greenest.

A very striking example of the power of leguminous plants to enrich the soil in nitrogen was furnished by Mr. Schultz, a farmer who owned the farm of Lupitz, in Altmark, N. Germany. The soil was little better than sand when he came into possession of it, and he could not afford to buy nitrogenous manures to bury in it, neither did he feed cattle to provide farmyard manure for it. He adopted the system of green manuring. He grew leguminous crops, chiefly lupines, and ploughed them in, and he manured his land with potash and phosphates, following Liebig's

recommendations, and he also limed it, but he put on no nitrogenous matter. The result was that his land grew more and more fertile. He used to plough in *all* his leguminous crop; by and by he reaped it, but still the fertility of the land increased. At first he followed his green manuring with a crop of rye, for the land was too poor to grow other cereals, but by and by he found he could grow oats and barley, and, in short, after a period of twenty years, he had converted a sandy waste into a rich, fertile soil containing abundance of nitrogenous matter. He declared that the nitrogen in his soil came from the air, and that the leguminous plants had brought it.

He called them *nitrogen collectors*, and the cereal crops he called *nitrogen consumers.*

This remarkable experiment soon gained notoriety, and farmers and scientists came annually in numbers to see it; and the impression left on their minds, when they compared this fertile farm with the barren, sandy land adjacent to it, was that leguminous plants at least must surely have the faculty of making use of the free nitrogen of the air.

It had the effect of causing a number of the scientists who had charge of agricultural experiment stations to institute experiments anew, to test again the old vexed question.

The first of these to arrive at satisfactory conclusions were Professor Hellriegel and his coadjutor, Dr. Wilfarth. They began their experimental inquiry in 1883, and three years later, in 1886, Hellriegel communicated to the Agricultural Section of the German Naturalists, at their meeting in Berlin, the interesting information that he had succeeded in proving that the leguminosæ were able to assimilate the free nitrogen of the air, and what added immensely to the interest of that fact was the curious way in which they did it.

I am not aware that the subject of Hellriegel's discovery has ever been formally brought before the notice of the Society, although most of the fellows present are doubtless well acquainted with it; but as it is what is called an epoch making discovery, I think a short description of it, even at this late date, would be welcome to some of you,

and an occasion like this is an appropriate one for the purpose. Time will not permit me to do more than trace its salient features in brief outline.

The gist of Hellriegel's discovery is this,—he found that leguminous plants of the sub-order Papilionaceæ were able to make their albuminoid matter by assimilating the free nitrogen of the air, and that that power was associated in some way with the growth of warty tubercles on the roots of the plants, and that these tubercles contained peculiar cells called bacteroids, due to the agency of bacteria which entered the roots of the plant from the soil.

I shall explain how he came to the full possession of that knowledge immediately, but in the first place I would like to refer shortly to the tubercles or nodules themselves.

Hellriegel did not discover the nodules. They have been known for a long time. The first mention of them that I am aware of was made by the famous Italian anatomist Malpighi, who described them in the year 1660. He thought they were galls, but he was surprised to find that they never contained eggs or larvæ. Coming to recent times, Treviranus describes them in a paper communicated to the Botanische Zeitung in 1853, but the first careful description of them was made by Woronin in 1866. He studied those found on the roots of *Alnus glutinosa* and *Lupinus mutabilis.* He described them as consisting of two distinct kinds of parenchymatous tissue, an inner and an outer, separated by a layer of vascular bundles proceeding from the vascular bundles of the root of which they were lateral excrescences. He noticed that the outermost cell of the inner parenchyma multiplied by division, and that the older cells contained a slimy mass of plasma, full of tiny little bacteria-looking bodies, which, when put into water, moved about just as bacteria do, and he thought that they were the cause of the nodules.

Erikssen, in 1874, published a paper accurately describing the development of the nodules on the roots of the *Faba vulgaris,* and observed that the region where the bacteroids were rapidly multiplying by division was entered by the hyphæ of a fungus, which appeared like a knotted thread ramified through the mass.

Frank and Prillieux, in 1879, described them, and regarded them as due to the attack of a parasitic fungus.

Schindler, at the same time, studied them, and came to the conclusion that the fungus was associated with the leguminous plant in a symbiotic manner; and Brunchorst, some years later (1885), described the nodules as store chambers, where the plant laid up a store of albuminoid matter which it utilised during ripening.

This view was suggested before by De Fries (1877), who held that the nodules were absorbers of nitrogen, which the plant utilised for making its albumen.

Schindler, in 1885, thought they were connected with the plant in a symbiotic manner, and that their function was to absorb nitrogenous organic matter from the soil.

Ischirch thought that these nodules grew best on soils that were poor in nitrogenous matter, and that they not only stored up nitrogen for the use of the ripening plant, but that they also went back partly to the soil and enriched it in nitrogenous matters also.

It was when observations and views of that kind were current that Hellriegel and Wilfarth published an account of their experiments.

These experiments commenced, as I said, in 1883. He found that when he grew leguminous plants and gramineous plants, say peas and oats, in the same soil—a soil consisting of sand, to which nutritive solutions were added—that the oats grew and flourished in proportion to the quantity of nitrate of soda supplied in the manure. When the amount added was small, the growth was small; when the amount was doubled, the growth was doubled; when the amount was trebled, the growth was trebled; and so on, until sufficient was added to produce a full crop, when, of course, the further addition of nitrate produced an ever-diminishing increase. It was quite plain that the oats derived their nitrogenous food precisely from the nitrate of soda provided for them. The peas, on the other hand, grew in quite a capricious manner; showing that they were not dependent for their nitrogenous food supply on the nitrate of soda, or at least not on it alone. As a matter of fact, the pot which got least nitrate grew the largest plants.

He further noticed that when the plants were grown in a poor soil—poor as regards nitrogen—they all came up equally well at first, and made a healthy braird, but as soon as the supply of nourishment contained in the seed was used up, they began to grow pale and yellow, and the oats died down. The peas, however, did not die down, but after a period of ill-health they began to regain their green colour, and thereafter their growth was rapid, and eventually they attained to full development.

He found that those plants that flourished best had most nodules on their roots, and those that were most backward had fewest.

This proved that vigorous growth and the development of root nodules were related to each other in some way.

To test whether the growth of the nodules was dependent on the attack of micro-organisms in the soil, he grew some peas and other leguminous plants in pots whose soil he had previously sterilised by heating, and he found that in such soils the peas succumbed just as the oats had done; there was no revival of colour and strength as before. When, to such a sterilised soil, he added a little of a fertile soil, in which peas grew on a few cubic centimetres of the watery extract of such a soil, the peas grew as before, and produced nodules on their roots. When he planted his peas in a sterilised soil to which nitrogenous manure was added, the peas grew, but they did not produce any nodules on their roots.

What was proved then by these experiments was, that leguminous plants could grow in a soil supplied with proper nitrogenous nourishment just as other plants could, but that they could also grow in soils containing very little nitrogenous matter if well supplied with other essential manurial ingredients, and that the plants contained far more nitrogenous matter than was contained in the soil; that this gain of nitrogen was dependent on the growth of nodules on the roots, and in proportion to their abundance; that the appearance of nodules was possible only in soils where a certain organism, or certain organisms, were present, and not otherwise; that the interference of these organisms enabled the plant to take up free nitrogen, either by its roots or by its leaves, from the air in the soil, or from the

air above the soil, in some unknown manner; that in the nodules there was a supply of nitrogenous matter which disappeared as the plant grew older, and that some of the nitrogenous matter of the nodules, and the organisms along with it, found their way back to the soil, and caused it to become richer in nitrogenous compounds.

This beautiful, interesting, and important discovery was, as I have said, first communicated by Professor Hellriegel and his coadjutor, Dr. Wilfarth, but there were a good many others engaged in the same inquiry, and whose experiments led to similar conclusions. Chief among these were Professor Prazmouski, Berthellot, Attwater, and Marshall Ward. The last of whom has shown, in a paper read before the Royal Society of London (1887), that the organism which attacks the roots of the leguminosæ, causing the growth of nodules, is not a bacterium, but a fungus whose minute germs are all but universally distributed in the soil.

The much debated question is now solved. The loss which is constantly going on over the world in the conversion of combined into free nitrogen is being constantly recouped by the conversion of free atmospheric nitrogen into combined nitrogen by at least one sub-order of plants that is found abundantly distributed all over the world.

The question naturally arises, are the leguminous the only kind of plants possessing this faculty of nitrogen assimilation? It would add vastly to the wonder of the process if that were so, and it would invest this sub-order of plants with a fascinating and absorbing interest. It is not natural to suppose that this power should be limited to only one sub-order of plants, and it would seem that other orders of plants are now recognised as in active, though it may be feeble competition. There is, however, one important set of plants that has been found to possess the faculty in a marked degree, viz. unicellular algæ, which, though among the most minute of plants, make up by their number what they lack in size. This very important discovery was made by Berthellot and André. They found that soils in which no visible plants were growing, and from which all combined atmospheric nitrogen was excluded, did become richer in nitrogen, whose only source can be the free nitrogen of the air; and a microscopic examination of such soils shows the

presence of minute unicellular algæ, which they found to be the active agents in that fixation.

That being so, there is no end to the possibilities of nitrogen assimilation by plants, for these unicellular plants resemble the cells of which most plants are composed, and it may yet be found that all plants possess in some degree, however small, the power of assimilating free nitrogen by their leaves. In most cases such power of assimilation may be so small in comparison with the demands which the plants make upon the nitrogenous matter in the soil, as to entirely escape observation until some specially devised methods of detecting and determining it are provided.

Before closing my remarks I would ask you to recall the results I have already referred to that were obtained by Georges Ville. He knew nothing about the nodules on the roots of the leguminous plants he grew, nor did he know what was the *modus operandi* by which the plants he worked with obtained their nitrogen, but he discovered the main fact, that they did assimilate free nitrogen, and that the power to do so was not confined to the papilionaceæ, but shared by plants of other orders. Moreover, he laid down quite accurately the conditions under which that assimilation took place. And as it is right that those who have been pioneers, and who have made important discoveries, should get full recognition, it is important to recall the fact that Ville's discovery was made forty-five years ago, and that his experiments were not matters of doubt or hearsay, but experiments whose results are all carefully and accurately recorded.

I have called this paper "The nitrogenous food of plants." It might be expected that I should proceed to describe in detail the various forms in which nitrogenous matters are provided for plant food. Any such description would far exceed the bounds of time at my disposal and of the patience at yours. I need only say in a sentence that numerous as the forms of nitrogenous food are, they are convertible into one very soluble form—nitric acid—which is believed to be the form in which chiefly, if not solely, plants take up their nitrogenous nourishment from the soil. Moreover, it is known that there are processes going

on in the soil whereby nitrogenous matters are converted into nitric acid; and that these processes, like most other chemical processes going on in the soil, are achieved through the instrumentality of living organisms. The characters of some of these organisms, their life history, the work in which they are engaged, and the means by which that work may be controlled in some measure, so as to serve specific ends, will, I understand, be demonstrated at an early meeting of the Society, and it is to form a kind of introduction to that practical aspect of the subject that I have asked you to listen to this short historical sketch.

EXPERIMENTS WITH NITRAGIN. By WILLIAM SOMERVILLE, D.Œc., D.Sc., Professor of Agriculture, Durham College of Science.

(Read, Thursday, 14th January 1897.)

Those who have been following the various developments of "the nitrogen question" during the past few years would be more or less prepared for the announcement that appeared in the "Deutsche Landwirtschaftliche Presse," on the 8th of April last, to the effect that the bacteria, which establish themselves on the roots of Papilionaceous plants, and enable them to utilise the free nitrogen of the air, were on sale as a commercial article by the firm of Meister Lucius & Brüning's successors at Höchst am Main. The work of many distinguished investigators during the past decade had established the fact that the Papilionaceous family of the Leguminosæ could make use of the supplies of atmospheric nitrogen in a way that was impossible for other plants. This power, however, is not inherent in the plants themselves, but is due to colonies of bacteria, which find a habitation in the wart-like nodules that are normally present in abundance on their roots. Without these bacteria the plants in question are in no better a position than others, and although our clover, peas, vetches, etc., may usually be trusted to find in the soil a sufficient number of the particular bacteria that they consort with, still there is always the chance that

these minute organisms may be absent, and that, in consequence, the vigorous development of the plants may be prevented. Professor Nobbe, of Tharandt, and Dr. Hiltner, devoted much attention to the subject, and proved, amongst other things, that each Papilionaceous plant has its own varietal, if not specific, organism, and that for full development it is necessary that the roots of a Papilionaceous crop should have access to the bacterium which is specially adapted to it. They therefore instituted a series of pure cultures of the various varieties of bacteria that inhabit the roots of our more important Papilionaceous plants, and having patented these cultures, they entrusted their manufacture to the well-known chemical firm above mentioned. This pure gelatinous culture is known as "Nitragin," and is sold at M. 2·75 per bottle, this quantity being sufficient to dress a morgen. It will thus be seen that for 4s. 6d. one can obtain as much Nitragin as will treat an acre, so that if it produces practically any good effects at all, its use can hardly fail to be profitable.

To apply the Nitragin to the land or the crop one is recommended either to mix it with water and then to add the seed to the solution immediately before sowing, or to mix it with some soil and afterwards scatter the mixture over the field.

Early in May I obtained a few bottles of Nitragin, and at once started some small experiments to test its practical value. Without going into the details of the arrangement and conduct of these experiments, I may say that I was careful (*a*) to apply the same quantity of seed to comparative plots, (*b*) to see that the Nitragin was not exposed to light, and was liquified at a temperature of less than 100° F., and (*c*) that in the various cultural operations of covering the seed, weeding the plots, etc., the worker should never go from inoculated to uninoculated ground. As a matter of fact the weeding was all done from planks, each plot being provided with a sufficient number, which were utilized as occasion required.

EXPERIMENTS WITH PEAS.

Each plot consisted of a row 24 feet long, an interval of $2\frac{1}{2}$ feet occurring between adjoining rows. Five

grammes of Nitragin were taken for each plot and mixed with half a pint of water, after which the seed (1 pint) was poured into the mixture and rendered thoroughly wet. Dry sand was next added to absorb the surplus moisture and facilitate the distribution of the seeds. The peas ("Dicksons' First and Best") were then sown in a drill and covered in the usual way. This experiment was carried out in duplicate. The following are the weights of produce in an air-dry condition:—

	"A" Plots.		"B" Plots.		Total Weight of Seed, Straw, and Husks.
	Seed.	Straw and Husks.	Seed	Straw and Husks.	
	oz.	oz.	oz.	oz.	oz.
Not Inoculated .	33·75	37·50	44·50	40 00	155·75
Inoculated . .	39·25	38·75	45·50	42·50	166·00
Gain by Inoculation	5·50	1·25	1·00	2·50	10·25

In both sets of plots the Nitragin has apparently increased the yield, the gain of total produce being 6·6 per cent.

EXPERIMENTS WITH BROAD BEANS.

This experiment was carried out in exactly the same way as the preceding one, except that here the rows were 2 ft. apart, and only two thirds of a pint of seed ("Early Long Pod") was employed.

	"A" Plots.		"B" Plots.		Total Weight of Seed, Straw, and Husks.
	Seed.	Straw and Husks.	Seed.	Straw and Husks.	
	oz.	oz.	oz.	oz.	oz.
Not Inoculated .	38·50	59·50	45·75	58·75	202·50
Inoculated . .	35·25	54·50	34·75	54 25	178·75
Loss by Inoculation	3·25	5·00	11·00	4·50	23·75

In this case the inoculation failed to increse the yield, and, as before, the "B" plots confirmed the "A"s. The total produce is 11·7 per cent. less when Nitragin was added than when it was withheld.

EXPERIMENTS WITH LUCERNE AND BROAD RED CLOVER.

Here each plot measured 24 ft. by 9 ft., a path $2\frac{1}{2}$ ft. wide being left between adjoining plots. Three ounces of seed were employed for each plot of lucerne, and $1\frac{1}{2}$ oz. for each clover plot. In neither case were the plots duplicated. The produce was weighed green immediately after cutting, with the following result.

	Weight of Lucerne.	Weight of Clover.
	lbs.	lbs.
Not Inoculated . .	105	159·5
Inoculated . . .	102	155·0
Loss by Inoculation .	3	4·5

In neither case did the Nitragin benefit the plants, the uninoculated produce being heavier by 2·9 per cent. in the case of the lucerne, and 2·8 per cent. in the case of the clover, than that grown upon inoculated ground.

It will thus be seen that only in the case of the peas did the application of Nitragin result in an increase in the yield, but in any case the variations in the weights of of produce are too small to make it possible to say definitely that the inoculating substance had affected growth either one way or another.

These experiments were carried out in a garden attached to the College, in which it may be assumed that peas and beans have frequently been cultivated during recent years. As the soil will thus be well supplied with the bacteria that associate with the roots of these plants, it is not surprising that the application of a pure culture of these bacteria should have been inoperative. But as regards red clover and lucerne, it may safely be assumed that neither of these plants has ever been *cultivated* in the garden, and the probability is that not a single plant of lucerne ever grew in the garden or indeed in any fields in the neighbourhood. The conditions, therefore, were to be regarded as distinctly favourable for exhibiting the action of the specific bacteria of these plants, and yet they faild to produce any effect.

Our experiences in the North of England appear to have been much the same as those of the few other investigators who have tried Nitragin in a practical manner in two or three other parts of the country. Nor does a greater measure of success appear to have attended the use of the substance on the Continent. The manufacturers of Nitragin recently sent a communication to the press, in which they contended that the many cases of failure that had been brought to their notice were to be ascribed to lack of care on the part of investigators, who, it was asserted, had exposed the Nitragin to too much heat or light, or had allowed the bacteria to be conveyed from inoculated to uninoculated ground. Such an explanation carries no conviction to the mind of anyone who is acquainted with the inoculation of soil by bacteria. At a recent meeting of the Associated Chambers of Agriculture, held at Halle, Dr. Kühn gave an account of the experiments with Nitragin which had been carried out during last season by himself, Menzel, and Falcke. All the more important leguminous crops were made use of in these investigations, with the result that in no case did Nitragin produce an increase that could be said to be beyond the range of experimental error admissible in field experiments. In some cases the uninoculated crop was considerably better than that which had been treated with Nitragin, and Kühn finishes his paper by expressing the hope that improvements in the methods of manufacture or application may yet make Nitragin of service in agriculture and horticulture.

There is no doubt that Nitragin will next season get a very careful and extended trial on the part of scientists and practical farmers, although it would have been more encouraging had the trials of the past season given more successful results.

The Bacteria of the Soil, with Special Reference to Soil Inoculation. By R. Stewart MacDougall, M.A., B.Sc.

(Read 11th February 1897.)

Up till about twenty years ago the soil was looked upon as made up merely of so many bits of dead material—stone and lime, and clay, etc. Tillage was a mechanical operation, and changes that followed it were explained purely on chemical and physical grounds. In these last years, however, it has come to be recognised that the soil teems with myriad minute forms of life—useful, and harmful, and neutral; in a word, for the tiller of the ground the problem is not solely chemical, but also biological.

Many workers in soil bacteriology have given their attention to the exact numbers of germs present in the soil, and in different layers of it. It would weary the reader to give lists of the numbers which vary in a gramme (just over 15 grains) of earth, according to the circumstances, from only a few up to some millions. Let me rather give the general principles determining their number as enunciated by Maggiora:[1]—(1) The number of bacterial germs, in otherwise resembling circumstances, is in forest soils less than in arable land, and in these less than in the soil of inhabited places. (2) In non-cultivated soils the number of bacteria changes with (*a*) the geological formation and the height above the sea; (*b*) with the imperviousness or the aeration of the soil, the germs being much less numerous in the former than in the latter; (*c*) with the nature of the soil,—sandy soil is less rich in bacteria than, say, humus soils. (3) In cultivated soils the number of germs increases with the culture activity and with the bringing of dung. Strongly dunged soils are much richer than poorly dunged or undunged. The greatest bacterial richness is at a depth of 8 to 20 inches; below this the number quickly decreases. This is true for both cultivated and non-cultivated soils.

If I say that Kramer, as an average of three experi-

[1] Maggiora, *Journal de la Agricole du Brabant*, 1888.

ments with the same soil, found in one gramme of earth—

At a depth of about 8 inches	. . .	650,000 germs,
,, ,, 20 ,,	. . .	500,000 ,,
,, ,, 28 ,,	. . .	276,000 ,,
,, ,, 39 ,,	. . .	36,000 ,,
,, ,, 47 ,,	. . .	5,600 ,,
,, ,, 55 ,,	. . .	700 ,,
,, ,, 64 ,,	. . .	only a few,

perhaps it will be asked how it is possible to make such exact calculations. A survey of the methods will show the problem not to be as difficult as it seems. If the earth sample be taken from the upper layer of the soil, we do it directly with a sterilised spoon, and then place the sample in a sterilised tube plugged with cotton wool. If the sample falls to be taken from the deeper layers, the above-mentioned method will not suffice, as in digging, the earth of the deeper layers will become mixed with parts from the upper layers, which will tumble in. To obtain an accurate sample from a layer of any depth, Frankel's borer is employed. The boring body of this instrument is about 1½ inch in diameter. An inch or two above the boring point is an opening between 4 and 5 inches long and about 1 inch deep. This opening is destined for the earth sample. The borer, with a handle which can be lengthened out to 5 feet, is pressed into the soil, and the mechanism is so arranged that as long as the borer be twisted from right to left the opening mentioned above as in the side remains closed. When the desired depth has been reached, by turning the borer in the opposite direction the covering to the opening is pushed back and the opening exposed; the earth falls in, the opening is again closed, and the sample pulled up. One gramme of this earth is carefully weighed out and placed in a quart of water, which has been sterilised by boiling, the mixture being thoroughly shaken. Meanwhile one has ready a glass tube containing the gelatine nourishing material for the bacteria. The gelatine has been rendered germ free by repeated heating in a steam bath. This gelatine, when liquefied by a gentle warming, has added to it carefully by means of a sterilised pipette 1 ccm. of the above mixture of water and earth. After a thorough mixing, the entire contents are poured

out of the tube on to a gelatine plate. Within a very short time the gelatine grows stiff, and holds, caught at certain points, the organisms. The isolated bacteria begin to grow and multiply by fission, and soon each has given rise to a colony. It is taken for granted that each colony has arisen from one individual germ, and by counting the colonies one gets the number of germs present in the 1 ccm. of the earth mixed in the water, and can thus calculate the number in the quart, *i.e.* in the gramme of earth. The colonies differ in external appearance, and each is confined to members of the same species. To get a pure cultivation of a particular species, one removes with a platinum needle a small part from a colony, and inoculates a fresh gelatine tube. In general outline, then, this is the method, but in very exact work other points must be attended to, *e.g.* certain bacteria only grow in absence of oxygen (anaerobic), and such must be cultivated accordingly. Questions of temperature, and differences in nourishing media to suit the varying bacterial tastes must also be considered.

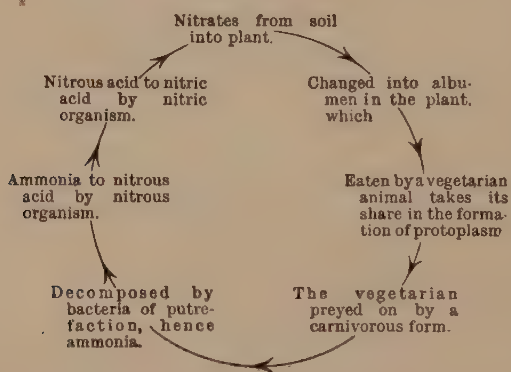
BACTERIA OF THE SOIL.

In the soil are a very large number of different species, some of which have been investigated and proved harmful or useful, but many more, as far as research has gone, have not yet been proved to have any significance as regards man himself or man's cultural operations. I propose to choose out of the mass three sorts, all of much importance to agriculturists, viz. :—

1. The Putrefactive.
2. The Nitrifying.
3. The Nodule forming Bacteria of Leguminosæ.

There are a number of bacteria which act on nitrogenous organic compounds in the soil and cause putrefaction, resolving the albuminous organic matter into simpler principles. We place as manure on our land complex organic substances, which by the aid of the putrefactive germs are rendered simpler, and brought into conditions such that they can be assimilated by the plant. When as a result of the action of the putrefactive bacteria on albumen, ammonia, say, is produced, this is seized and

acted on by other organisms, the so-called nitrifying bacteria; the nitrous organism converting the ammonia into nitrous acid, this nitrous acid by the agency of the nitric organism passing into nitric acid, from whose union with a base come the nitrates so important as the form in which plants obtain that nitrogen, without which their growth and development is impossible. There is then a sort of circle of changes by which the nitrates taken up by the plant once more find themselves as nitrates in the soil, on the completion of the circuit in which bacteria play so important a part.



"Death," as Liebig says, "the source of a new generation"; or, as Klein quotes, "from earth to earth."

Morphology of the Nitrifying Organisms.—Globular to begin with, but later, oval and somewhat elongated. The nitrous organism is larger than the nitric, and measures $\frac{1}{25000}$ inch.

Conditions which favour Nitrification with Annotations.—1. *The presence of the organisms.*—These organisms vary in number greatly in different soils. The more highly cultivated soils will contain them in greatest quantity. Where they are few in number what has been termed "microbe-seeding" may be wisely practised, *i.e.* soils which, owing to their deficiency in these organisms, can be looked on as so far sterilised, could have added to them soil which from the conditions was known to be rich in nitrifying germs. If the new environment were favourable the

introduced bacteria would rapidly multiply and spread. This is a favourable place to notice one of the values of stable manure. "Dung," as Hilltner has expressed it, "is the leaven of the agricultural soil," meaning that in adding it one gets, over and above other well-known advantages, a supply of vigorous nitrifying organisms.

2. *Access of Oxygen.*—This is why the bacteria of nitrification occur in greatest number towards the surface, and decrease with the depth. A new meaning is hereby given to tillage and good cultivation, as these ensure a good circulation of the necessary air.

3. *Light acts injuriously.*

4. *A certain moisture* is necessary, but marshy ground will lack the germs.

5. *A suitable temperature.*—In this case, say, between 90° and 100° F.

6. *A base with which the nitric acid, on its appearance, can combine.*—It is an interesting fact that as a result of the activities of soil organisms, their own further development may be inhibited. Thus, yeast is killed by excess of alcohol produced by itself, and so, too, with bacteria. Their own products may forbid their further growth. In the world of medicine, by inoculation of the matter prejudicial to the life of certain bacteria, we can put an end to them. The presence of a base then prevents the accumulation of nitric acid. A favourite base is lime, and among the numerous advantages of lime in a soil, I desire at present to single out its favouring so largely the development of the nitrifying bacteria.

7. *The other necessary plant foods.*

And now there is a dark side to this story. Research has proved the presence in soils of denitrifying organisms, which may bring the work of the useful organisms to nought. Their work is a reducing one, the nitrates being decomposed with an ultimate giving off of free nitrogen. Instead of being a gain, these denitrifying bacteria occasion a loss. Generally it may be stated that the conditions under which these harmful organisms flourish are the opposite to these we have mentioned as favourable to the nitrifying germs.

THE BACTERIA OF LEGUMINOSÆ.

Of the substances which are taken in by the roots of plants, the most important in plant metabolism are the nitrogenous compounds. Generally it may be stated that while plants can and do take in oxygen as a free gas for their respiration, they are quite unable to make use of free nitrogen. The nitrogen so necessary in the plant economy can only be absorbed in the combined state, say, as nitrates.

For long this was held to be true of all orders of plants, until it was noticed that while in soils deficient in nitrogen most plants came to nought, yet members of the order Leguminosæ (peas, and clovers, and vetches) grew quite well, and left the land after their growth richer in nitrogen than before. When it came to be admitted that leguminous plants must and did make use of the free uncombined nitrogen, men cast about for an explanation of their advantage as regards nitrogen, and several theories were advanced before it came to be admitted that in the nodule formation was to be found the real solution of the problem.

These warts, or swellings, or tubercles—as they are variously called—were shown to be little houses inside which lowly plant forms lived in partnership with the pea, or bean, or clover, deriving support from the plant, and repaying this support by fixing the free nitrogen that surrounded the roots, and forming it into compounds that were absorbed by the leguminous plant.

These swellings had been written of long before their real origin was discovered. As far back as 1687 Malpighi wrote of these as galls, and, coming nearer our own time, they were looked upon by some as a sign of a diseased condition, and by others as resulting from nematode attack. Now we know that these nodules only appear on the roots in case of infection with a bacterium, the Bacillus radicicola of Beyerinck (*Rhizobium leguminosarum*, Frank). This bacillus is widely spread, and can be obtained in quantity, for examination, if perfectly fresh leguminous roots are laid in water and left to steep for a few hours in a warm room. Amidst the bacteria, which

will have rendered the water cloudy, will be found many of the nodule-making forms. The bacteria penetrate a root hair or a non-cuticularised epidermal cell (the young parts are the seat of infection, the older parts of the root not allowing an entrance), where they multiply at the expense of the cell contents. The irritation set up in the cortex cells, in which the bacteria ultimately find themselves, gives rise to repeated cell division, and the wart is formed. Finally, these bacteria take on a forked or Y-shaped appearance, when they are known as bacteroids. The full significance of these bacteroids will appear later, sufficient here to say that their contents are finally absorbed by the host plant. A certain number of bacteria remain behind, which, on the breaking down of the nodules, are set free again in the soil, where they may proceed to new infection.

Frank had previously noticed that nodules did not appear on leguminous plants grown in sterilised soil, but the proof that the Leguminosæ are not able to make use of the free nitrogen in absence of nodules, but only when nodules are present in their roots, was given by Hellriegel and Wilfarth, after a series of very accurate recorded experiments. Their experiments showed that peas and lupins grown in soil sterilised, but with all the necessary plant foods added save nitrogen, died off without any nodule formation as soon as the original store of nitrogen present in the seeds had been exhausted. Peas and lupins, on the other hand, sown under the same conditions, save that a little soil was added from a field where peas and lupins had been growing the year before (in which soil it was reasonable to expect the infecting bacteria to be present), showed a large formation of nodules and a most excellent growth.

Many workers, British and foreign, have since verified these results, but Professor Nobbe and Dr. Hilltner, of Tharand, have taken a step in advance by being the first to induce nodule formation by inoculation with pure cultures. Here is the method of making such pure cultures: Take a fresh nodule and wash it carefully. After drying it in blotting paper, drop it for a moment into corrosive sublimate, to kill any bacteria on the surface. Next wash it with absolute alcohol. Having

sterilised a scalpel by heating in a flame, cut the nodule. Dip a platinum needle into the cut surface, and streak the gelatine already prepared. It is well to have a large surface of gelatine, as the Bacillus radicicola is an aerobic form. It is important to remember that this bacillus will not grow on the ordinary gelatine, but there must be incorporated with the gelatine-nourishing medium a decoction of leguminous shoots or leaves. Having obtained in this way, after a few days, a pure growth of the bacillus, in order to inoculate plants growing in pots some of the bacilli are transferred to water, a little of which may be sprinkled over the soil in which the plants are growing; or, better still, by means of a glass tube the mixture is introduced to the deeper layers, near the roots. The experiments of Nobbe and Hilltner aimed at winning information and clearness in three directions, viz.: (1) What are the true factors and occurrences by which a nodule-beset leguminous plant is able to make use of the free nitrogen? (2) What is the action and efficacy of the nodules in soils holding different quantities of nitrogen? (3) Are the bacteria from the warts of the different leguminous species one and the same species of bacterium, or has each leguminous group or species its own distinct nodule-former?

As to Question 1.—Some hold that the nitrogen assimilation is by means of the green leaves, others that the bacteria are the chief agents in taking up the free nitrogen. Nobbe and Hilltner believe strongly that the power is vested in the bacteroids, which, arranged in the form of a network, expose a large surface to the air, to which the bacteroids come into relation as regards nitrogen in the same way as the gills of a fish to oxygen. The conclusions from their experiments so far are: (*a*) Nodules whose bacteria have not followed on to the bacteroid stage (as happens in certain circumstances) are of no value to the plant, the bacteria in them being out-and-out parasites, and performing no nitrogen assimilation. (*b*) The stronger in life the bacteria are, the less is the tendency to become bacteroids; the stronger the nodule-possessing plants, the easier is the changing from bacteria to bacteroids. (*c*) With bacteroid formation comes nitrogen assimilation.

Question 2.—Hellriegel experimented with sterilised soil, and grew his plants with the conditions—no nitrogen and non-inoculated, and no nitrogen but inoculated. Of greater complexity are the experiments of Nobbe and Hilltner, who added to some of the sterilised soils (left sterilised or else reinoculated) varying proportions of nitrogen, and noted results. Their answer to Question 2 is, that the effect of the nodule reaches its full worth when the soluble nitrogen of the soil is almost used up by the growing plants. The more a soil contains of bound assimilable nitrogen so much the later will the differences stand out externally between inoculated and non-inoculated plants. Quickly-growing leguminous species, like peas and vetches, which sooner exhaust the supply of combined nitrogen, will show the effects of inoculation earlier than clovers or lathyrus, which, growing at first more slowly, make more trifling demands on the soil nitrogen.

Question 3.—Do the bacteria from the nodules of different leguminous plants belong to one and the same species? Beyerinck is of opinion that the bacteria cultivated from the different species of Leguminosæ are not identical, though certainly very similar. He distinguishes two groups: (1) Those whose large colonies are more hyaline and give rise to bacteroids, forked or roundish. Such are bean, vetch, broom, medicago, melilotus, clover, pea, lathyrus. (2) Those with opaque, dull white colonies giving bacteroids seldom branched, but more like bacteria, *e.g.* ornithopus, lotus, lupinus, robinia, caragana. Nobbe and Hilltner believe that though the bacteria springing from the different leguminous species can scarcely be distinguished from one another externally, yet in their effect and behaviour and attitude to the plants they show noteworthy differences. For example, bacteria won from nodules on the pea, infect most powerfully other pea plants, and act most beneficially on them; infect and act less favourably to plants not peas, but closely related to them, but produce no impression on leguminous species like robinia or clover, whose affinity with the pea is not close. *Vice versa*, bacteria from the nodules of the red clover infect other red clover plants, but are quite ineffectual on peas.

Nobbe and Hilltner, however, emphasise that the cultures from different Leguminosæ have not to be looked on as different bacterial species, but only as adaptable forms, forms adapted to the varying leguminous species by their living on different plants. To make this clear, they have coined a new phrase—neutral bacteria, viz. those living in the soil with no special biological adaptability to any special leguminous species, but able to get in a weak degree into symbiosis (partnership) with all genera of Leguminosæ. These neutral bacteria, having penetrated the roots of a special leguminous plant, form nodules. They multiply, and their descendants have been so influenced by the host plant that, having ceased to be neutral like the original parent forms, they effect their full strength only on the same leguminous species, and lose their power to set up infection in any other. Here will be found the explanation of strange Leguminosæ forming nodules on their roots, which nodules go on increasing from year to year in number and efficacy. Leguminous plants then will only, with certainty, show nodule formation if the soil contain either the germs accustomed to the planted species or else neutral germs.

I would now call your attention to some experiments relating to Question 2:—

I. AN EXPERIMENT WITH PEA (*Pisum sativum*).

In this experiment 6 pots were taken and filled with a mixture of 4 parts quartz sand and 1 part garden earth, the whole being sterilised, *i.e.* all germ life was killed by heating. In each pot 5 pea plants were sown in the beginning of June.

Pot 1	was inoculated with	pure cultures of	Phaseolus	bacteria.
,, 2	,,	,,	Pea	,,
,, 3	,,	,,	Clover	,,
,, 4	,,	,,	Robinia	,,
,, 5	,,	,,	Lupin	,,
,, 6	was left uninoculated.			

At first all the pots showed an equally good growth, but as time went on and the soluble nitrogen of the soil had been largely consumed, the effects of inoculation began to show themselves. The plants in the pot inoculated with pea bacteria, and, later, those in the pot inoculated with phaseolus bacteria were seen to be green, and were richly

flowering and fruit-bearing up till the autumn. The plants in the other four pots were quite withered by the end of August. On 20th October the plants were cut, and the above-ground parts analysed. For comparison, here are the results in the cases of the non-inoculated, inoculated with phaseolus, and inoculated with pea—

	Not Inoculated.	Inoculated with Phaseolus.	Inoculated with Pea.
Dry substance in gr. .	3·878	28·821	95·452
Nitrogen in the green substance in gr. .	0·055	0·852	2·791
Nitrogen per cent. of the dry substance .	1·43	2·96	2·92

That is, the plants inoculated with pea bacteria, compared with the non-inoculated, showed twenty-four times more of dry substance and fifty times as much nitrogen content.

At the time of cutting, the plants had for each experimental pot—

	Flowers still.	Fruits.	Seed.
1. Inoculated with Phaseolus bacteria . . .	18	41 (20 still unripe)	55
2. Inoculated with Pea bacteria	36	134 (77 still unripe)	161
3. Not inoculated . . .	0	2	3

II. EXPERIMENT WITH *VICIA VILLOSA*.

This experiment was conducted under the same conditions as the last, only the pots contained *Vicia villosa* plants instead of peas.

The most noteworthy thing about this experiment was that the best results were given with the vetch plants in the pot inoculated with pea bacteria (vetches and peas are nearly related), and the next best results in the case of inoculated with phaseolus bacteria. The plants inoculated

with clover, robinia, or lupin, soon began to show nitrogen hunger, shedding their leaves. The non-inoculated plants were ultimately quite leafless.

	Uninoculated.	Inoculated with Phaseolus Bacteria.	Inoculated with Pea Bacteria.
Dry substance in gr. .	4·292	63·929	93·693
Nitrogen in gr. . .	0·070	2·310	3·444
Nitrogen in per cent. of dry substance . .	1·84	3·61	3·68

EXPERIMENT III.

contains additional interest. The plants experimented with this time were red clover, five in each pot, and all the conditions of the other experiments the same.

In this experiment the inoculations with pea bacteria, with robinia bacteria, and with lupin bacteria showed in the first two no effect whatever, and with the lupin only a very limited effect.

Comparing the pea inoculation with the clover inoculation—

	Inoculated with Pea Bacteria.	Inoculated with Clover Bacteria.
Dry substance in gr.	6·23	70·99
Nitrogen in green substance in gr. .	0·108	2·136
Nitrogen in per cent. of dry substance .	1·74	3·01

As to flowers and fruit. On cutting in October, the five clover plants inoculated with clover bacteria had had 54 flower-heads, while the pot with clover plants inoculated with pea had only 8 flower-heads.

EXPERIMENT IV.

will have an interest for foresters. Robinia plants were inoculated, some with pea bacteria and some with robinia bacteria. The robinias inoculated with robinia bacteria greatly excelled the robinias inoculated with pea bacteria.

So far for laboratory experiments with sterilised soil. There has not yet been time to obtain many results from experiments made with pure culture inoculation on a field scale, and yet here, too, there is at least an earnest of success.

Three plots out in the open, each 120 yards square, were planted with ornithopus. The sowing was in May.

Plot 1 was inoculated with pure culture of ornithopus bacteria.
,, 2 ,, raw earth from another ornithopus field.
,, 3 was left uninoculated.
When these plants were revised in August, the non-inoculated plot averaged 2 small nodules per root.
Those inoculated with raw soil plot averaged 3 medium-sized nodules per root.
Those inoculated with pure ornithopus culture averaged 9 mostly large nodules per root.

Many experiments on a field scale have been started on the Continent, and, doubtless, during the year many more will be undertaken in Britain. Certainly a good case has been made out in the experiments in the experimental station at Tharand for the value of soil inoculation, and now field experiments under many conditions must give the final answer as to whether or not this special branch of soil inoculation is likely to prove advantageous.

As to Methods.—Where a soil is deficient in Bacillus radicicola there are two methods of infection—

1. The bringing to such a field a quantity of soil from another field in which the species of the plant to be sown has already grown well. This soil is then worked in. Dr. Salfeld, of Hanover, holds the honour of having employed this method on a large scale with gratifying results, getting good leguminous crops where such had refused to grow before. Difficulties in the way of using this method of inoculation on a large scale will occur, *e.g.* uncertainty, questions of cost and transit, the possible introduction of harmful forms, and so on.

2. There remains the second method, viz. Nobbe and Hilltner's method of inoculation with pure cultures. Such cultures can be made by oneself if the necessary bacteriological training is possessed, but if not, bottles containing the cultures can be bought from Lucius & Bruning, Hoechst a Main, at 2s. 6d. each. So far, cultivations of the following plants can be procured:—

Trifolium pratense or *repens* or *hybridum*, *T. incarnatum*, *Vicia villosa* and *sativa*, *Pisum sativum*, *Vicia faba*, *Medicago sativa*, *M. lupulina*, *Lupinus luteus*, *L. angustifolius*, *Ornithopus sativus*, *Onobrychis sativa*, *Lathyrus sylvestris*. Each bottle contains enough to supply half an acre.

In the inoculation with pure cultures there are two variations—

(*a*) *The inoculation with infected soil.* Take one of the above-mentioned bottles. Gently warm the bottle by placing it in lukewarm water (great care must be taken not to overheat—keeping in one's pocket for a few minutes is enough), and the gelatine with the culture is liquified. Pour this (thoroughly cleaning the bottle out) into a vessel containing sufficient water to moisten half a hundred weight of soil. Mix this liquid well with the earth. Then add some dry soil till a condition is reached when it can be conveniently spread. Work this into the field to a depth of 3 to 4 inches. Sow as soon as possible.

(*b*) *The inoculation of the seed directly.* As before, take a bottle and pour the liquified contents into 1½ pint of water (this will do for small seeds like clover, but for larger seeds use 2 or 3 quarts). Pour the mixture over the seeds, and mix thoroughly, making sure that each seed gets moistened. Then add some soil from the field to be sown, so that the seeds don't stick together in clumps, and when dry enough sow.

In both *a* and *b* I have given the quantities necessary to inoculate half an acre.

HINTS AS TO EXPERIMENTS.

To all intending to make experiment I would recommend that in each experiment, for purposes of comparison, three plots be dealt with. Let plot 1 remain uninoculated; let plot 2 be inoculated with infected soil; let plot 3 have the seed inoculated directly. In the case of experiment on these lines, for safety let the non-inoculated plot be sown before the inoculated, and, to prevent after infection, let great care be taken to have no traffic between the inoculated and the non-inoculated plots.

Experimenters will also note—

1. That the cultures are very sensitive to light, and heat, and drought, all of which destroy the efficacy of the bacteria. Therefore do not allow the inoculated soil or seed to become too dry, and do not allow the seeds to remain exposed on the surface.

2. The results of inoculation must not be looked for too early. Remember that the efficacy of the nodules only comes into full activity when the soil nitrogen has been used up. The more of this in the soil the later will the effects of inoculation show themselves.

3. In order that a proper judgment be passed as to the effect of inoculation in parallel experiment, a mere naked eye overlook is not sufficient and not trustworthy. There must follow a careful weighing. Dr. Hilltner told me of a case where Dr. Salfeld made an experiment with ornithopus, the pure cultures for which were supplied from Tharand. When, towards the end of the experiment, an inspection was made, there seemed, as far as the eye could judge, to be no difference between the inoculated field and the non-inoculated, and, as the plants in the latter also showed nodules, everyone thought this experiment had proved a failure. Just eight days after the inspection, the two crops having been cut in the interval, Dr. Salfeld wrote to Professor Nobbe to the effect that the inoculated plot had borne stronger plants than the non-inoculated, and that a careful weighing had given a twenty-five per cent. advantage in green substance to the inoculated over the non-inoculated.

4. It must not be forgotten that the condition of the soil has a most important influence on the results of inoculation. The—apart from nitrogen—necessary plant foods must be present in sufficient quantity. The nodules collect only nitrogen, so that the plants must find in the soil all the other foods. A chain has only the strength of its weakest link, and "a field is as poor as its most deficient fertilising principle." Apart from nitrogen, if there be only one of the other necessary foods not present in sufficient amount, then the capacity of the nodules will fail from the time when this substance begins to disappear.

5. The most profitable results of inoculation are likely to be in soils where nodule bacteria are naturally absent, and the least profitable where Leguminosæ have been greatly cultivated. Between these two there are all grades.

I cannot close this article without placing on record my indebtedness to Professor Nobbe and Dr. Hilltner, who received me at Tharand with great courtesy, and gave me every opportunity of becoming acquainted with the methods and experiments.

EXCURSION OF THE SCOTTISH ALPINE BOTANICAL CLUB TO CLOVA, IN JULY 1896. By WILLIAM CRAIG, M.D., F.R.S.E., F.R.C.S.E., Secretary of the Club.

(Read 11th March 1897.)

The Annual Excursion of the Club in 1896 was to Clova, a place exceedingly rich in botanical treasures, and one which is, and has been for generations, a great favourite with botanists. When the Club first visited Clova in 1872, the whole district was pastoral, and perfect freedom was permitted to all botanists. It is now, however, like many other of our highland glens, converted into a deer forest, and consequently there is sometimes a difficulty of access to these glens. The Club, however, were highly favoured in obtaining permission for a week in July to botanise the district. Permission was obtained from the proprietrix, Mrs. Macpherson of Glen Doll, through her agent, Mr. W. Gibson, W.S., Edinburgh.

The members of the Club left Edinburgh on Monday, 27th July 1896, with the 9.40 A.M. train for Kirriemuir. They travelled by the Caledonian Railway, the officials of which Company sent a private saloon carriage to Kirriemuir for the special use of the members. Kirriemuir was reached about 12.45 P.M. After lunch in one of the hotels the members had a very pleasant drive to Clova, and stayed at the Ogilvy Arms Hotel. Nine members of the Club attended this excursion, including our president, Mr. W.

B. Boyd. They were accompanied by Dr. Playfair, of Bromley.

In the evening a business meeting of the Club was held, when Professor F. O. Bower, Glasgow, and Mr. A. Somerville, B.Sc., Glasgow, were elected members. The election of two such distinguished members will greatly strengthen the Club. Bedroom accommodation in the Clova Hotel was very deficient, and three of the party had to be accommodated in a farmhouse half a mile distant.

Tuesday, 28th July.—The excursion to-day was to Glen Fee. The day was remarkably fine. Our new member, Mr. Somerville, sent specimens of the *Hieracia*, collected during this excursion, and also the specimens of the *Salices* to the Messrs. Linton; and other doubtful plants to Mr. Bennett of Croydon. Among the plants collected to-day may be mentioned—*Thalictrum alpinum*, L.; *Sagina Linnæi*, Presl.; *Oxytropis campestris*, DC., on the only known station for that plant in the British Isles; *Saxifraga oppositifolia*, L.; *S. nivalis*, L.; *S. stellaris*, L.; *S. aizoides*, L.; *Saussurea alpina*, DC.; *Hieracium eximium*, Marshalli, rare; *H. chrysanthemum*, Backh., plentiful; *H. lingulatum*, Backh.; *H. anglicum*, Fries; *H. anglicum*, var. *acutifolium*, Backh.; *Veronica alpina*, L.; *Salix lanata*, L.; *S. Lapponum*, L.; *S. nigricans*, Sm., crossed with *S. myrsinites* or *S. phylicifolia*; *S. mysinites*, L.; *Malaxis paludosa*, Sw., one specimen of this orchid was found by the president, which measured 4¼ inches in length; *Carex pauciflora*, Lightf.; *C. pulicaris*, L.; *C. echinata*, Murr.; *C. leporina*, L.; *C. alpina*, Swartz; *C. atrata*, L.; *C. rigida*, Good.; *C. pallescens*, L.; *C. panicea*, L.; *C. vaginata*, Tausch; *C. capillaris*, L.; *C. binervis*, Sm.; *C. Grahami*, Boott; *Poa glauca*, Sm., which Mr. Bennett says is the nearest to Smith's supposed *Cæsia* that he has seen; *Festuca rubra*, L., a hairy glumed form; *Aspidium Lonchitis*, Sw.; and the moss *Splachnum sphæricum*. They failed to find *Woodsia*.

Wednesday, 29th July.—The excursion to-day was to Craig Maud and the Astragalus Rock. The day was again fine, but not so hot as on the previous day. Although careful search was made, they failed to find any specimen of *Astragalus alpinus*, L., a plant which formerly was in great abundance on a rock at the head of the glen.

In the opinion of the members of the Club, this rare plant had been eradicated from Glen Doll. The plant, however, is known in two other localities in Britain, one in the Braemar district, Little Craigendal; and the other on Ben Vrackie, near Pitlochry. Another well-known Clova plant, which ought to have been seen to-day, was *Lactuca alpina*, Benth., but no trace of it was seen. They gathered some good alpine plants, including—*Arabis hirsuta*, Br.; *Sagina Linnæi*, Presl.; *Dryas octopetala*, L.; *Saxifraga nivalis*, L.; *S. hypnoides*, L.; *Epilobium angustifolium*, L.; *E. alsinefolium*, Vill.; *E. alpinum*, L.; *Linnæa borealis*, Gronov.; *Erigeron alpinum*, L.; *Saussurea alpina*, DC.; *Hieracium cerinthiforme*, Backh.; *Erica cinerea*, L., var. *alba.*; *Pyrola rotundifolia*, L.; *P. secunda*, L.; *Veronica serpyllifolia*, L., var. *humifusa*, Dicks.; *V. Saxatilis*, L.; *Salix nigricans*, Sm.; *S. phylicifolia*, L.; *Habenaria viridis*, Br.; *Tofieldia palustris*, Huds.; *Carex pauciflora*, Lightf.; *C. pulicaris*, L.; *C. rupestris*, All.; *C. canescens*, L., var. *apicola*, Wahl.; *C. rigida*, Good.; *C. Goodenovii*, Gay; and a form of which the fruits seemed affected by insect-puncture or fungus, and of which Mr. Bennett says some of the fruits seem quite *rigida*, others towards *Goodenovii*; *C. rariflora*, Sm.; *C. glauca*, Murr., luxuriant specimens; *C. pilulifera*, L.; *C. flava*, L.; *C. ampullacea*, Good.; *Poa nemoralis*, L., according to A. Bennett, "a *variety*, but seemingly not one in our books"; *Botrychium Lunaria*, Sw.; *Equisetum palustre*, L., var. *nudum*; *Tetraplodon mniodes*; *Hypnum Crista-castrensis*, L. By the side of the stream at "Jock's Ladder" was seen a large tree of *Salix caprea*, L. It is worthy of note that the following plants were found with abundance of fruit, unusually fine:—*Empetrum nigrum*, L.; *Rubus Chamæmorus*, L.; *Fragaria vesca*, L.; *Cornus suecica*, L., a plant not often found in fruit in Scotland; *Vaccinium myrtillus*, L.; *V. uliginosum*, L., sparingly; *V. Vitis-Idæa*, L.; *V. oxycocus*, L.; and *Trientalis europæa*, L.

Thursday, 30th July.—The excursion to-day was to Glen Fee and Glen Doll. The day was again dry and fine. Among the plants collected may be mentioned—*Arabis hirsuta*, Br.; *Geranium Robertianum*, L., var. *alba*; *Epilobium alpinum*, L.; *Vaccinium uliginosum*, L., in ripe fruit; *Salix Lapponum*, L.; *Malaxis paludosa*, Sw.; *Tofieldia*

palustris, Huds.; *Carex aquatilis*, Wahl.; *C. Goodenovii*, Gay, var. *atra*, Blytt; *C. præcox*, Jacq.; *Deschampsia cæspitosa*, Beauv., var. *brevifolia*; *Aspidium Lonchitis*, Sw.

Friday, 31st July.—The excursion to-day was to Little Gilrannoch. The day was again fine. The party went by Glen Doll, and past the White Waterfalls to the upper valley of the White Water, and then to the top of Little Gilrannoch. The *Lychnis alpina* was found at this station as abundant as ever. Among the plants collected may be mentioned—*Cochlearia alpina*, Wats.; *Lychnis alpina*, L.; *Cerastium semidecandrum*, L.; *C. triviale*, Link., var. *alpinum*, Koch.; *Arenaria Cherleri*, Benth.; *Armeria vulgaris*, Willd.; *Gentiana campestris*, L., var. *germanica*, Murbeck (non Willd.); *Juncus Triglumis*, L.; *J. castaneus*, L.; *Carex canescens*, L.; *C. rigida*, Good.; a form supposed by Mr. A. Bennett to be the var. *infuscata*, Drejer; *C. aquatilis*, Wahl.; and a variety supposed by Bennett to be var. *minor*, Boott; *C. rariflora*, Sm.; *Alopecurus alpinus*, Sm.; *Phleum alpinum*, L.; a form of *Equisetum sylvaticum*, L., supposed to be *tenuior*; and the moss *Diphysicium foliosum*.

The day was exceedingly fine, and the party returned from their long excursion in excellent health and spirits, less tired than during any of the previous days.

Saturday, 1st August.—After an early breakfast, the whole party left Clova at 7 A.M.; and after a pleasant drive, they reached Kirriemuir in time to catch the 9.35 A.M. train to Edinburgh. The officials of the Caledonian Company again sent to Kirriemuir a fine saloon carriage for the use of the members of the Club. Edinburgh was reached about 3 P.M. All the members were greatly delighted with their excursion to Clova. It is worthy of record that the Club experienced no rain during the whole of this excursion. In the words of the president: "The weather was delightful throughout, and not a drop of rain. I never remember a meeting when we did not even get our feet wet before."

ON THE PHOTOMICROGRAPHY OF OPAQUE STEM SECTIONS—RECENT AND FOSSIL. By R. A. ROBERTSON, M.A., B.Sc.

(Read 11th March 1897.)

Everyone engaged in research work or teaching has felt the great need of a method of reproducing accurately the diagnostic characters of timber as seen in transverse and longitudinal section. Drawing each surface by hand, in detail, is a slow process, even although such gave satisfactory results, which it does not, the personal equation of the artist always making itself felt. An ordinary razor-cut section is rather small, and does not present surface enough to exhibit, typically, all the characteristic appearances. Besides, the characters important for purposes of identification are apt to be lost sight of in the multitude of details presented, when such a section is micrographed. A large area is a necessity, as the character of the wood is not constant, but changes with age. There is the method of preparing large sections by means of the hand-plane.* This method, while giving excellent results *pro tanto*, is objectionable for this special purpose, because of the difficulty of getting such sections exactly transverse, of the tendency of the cell membranes to become torn, and of the time required in preparation of the block, even before sectioning can be begun, not to speak of the labour, patience, and time necessary to secure even one satisfactory preparation. Again, in dealing with rare or museum specimens, one cannot always get *carte blanche* to cut and carve the preparations for the purpose of sectioning as described.

The objections to these methods are still stronger when one is dealing with fossilised stems. The cutting of sections in this case, and the subsequent grinding necessary to obtain a preparation thin enough to be transparent, is a tedious process, requiring considerable manipulative skill, and the objections to cutting up museum specimens in this case are very pronounced. To overcome these difficulties, is the aim of the method which follows: to take the

* A magnificent series of hand-plane sections of British woods was exhibited to this Society some years ago by Professor Bayley Balfour. This series is in the Research Laboratory at the Royal Botanic Garden.

museum preparation, already polished or ground, as the case may be, and get a representation of its structure showing detail enough for purposes of identification and comparison, without in any way damaging the preparation.

PREPARATION OF THE SPECIMENS.

No sectioning is required, as only the specially-dressed opaque surface of the block of wood is micrographed. If one have the blocks of wood at one's disposal, the first thing is to get the transverse or longitudinal surface which it is desired to photograph as smooth and clean cut as possible. This is accomplished by aid of a heavy steel dressing-plane, the finishing strokes with the plane being all in the same direction. Avoid sandpapering the surfaces. In the case of specimens which have unfortunately been sandpapered, a new series of artificial characters, consisting of very fine striæ is introduced, and a photograph of such a surface presents a general "fuzziness" which very unpleasantly masks the diagnostic points. This may be remedied to a certain extent by rubbing the surface of the block with a wet sponge immediately before the photograph is taken.

In the case of museum specimens, which are polished or varnished, satisfactory results may be obtained by lengthening the time of exposure, varying the intensity of the light, and also the angle at which the incident rays from the radiant strike the surface. The varnished or polished surface acts to a certain extent as a mirror, and introduces some difficulties. The same difficulties are encountered in dealing with polished surfaces of silicified wood, but these troubles are overcome in the way above described. In well ground and polished fossil specimens, one obtains, with a little care, very sharp negatives, showing almost as much minute structural detail as in an actual micro-section—a result which cannot be looked for in the case of recent woods, unless they are very hard and highly polished.

The best results are got in the latter case, when the photograph is taken of the surface immediately after being dressed, before the pores have had time to fill with dust, or before any discoloration has set in.

FIRST METHOD.

APPARATUS.—That I have used is the photo-micrographic apparatus by Reichert, of Wien. It has the advantage that it can be used either vertically or horizontally, the change of position being accomplished in a fraction of a second. This is a real advantage, because one requires to vary the position of the camera when dealing with specimens where particular manipulation of the light is necessary to get the best results. On a table at one side of the apparatus, I have had fitted a Welsbach Incandescent Gas Light installation with a bye-pass. This I use for focusing, and find it much to be preferred to an Argand or a petroleum lamp, on account of the character and intensity of the light. It may not be amiss to advise the use of the apparatus without a funnel, which is continually in the way, and, in the case of rupturing of the mantle, entails nasty accidents. The Welsbach is fitted with a stand and clamp, so that it can be moved about in any direction, and put at any height that may be necessary. On the opposite side of the camera is fitted the radiant. This consists of a magnesium ribbon apparatus, arranged like the Welsbach, to permit of every freedom for moving as desired, either horizontally or vertically.

Having removed the microscope and all the microscope fittings from the camera, I affix, by means of an adapter, a half-plate photographic lens with iris-diaphragm into the front aperture of the camera, where the light-excluding capsule of the microscope tube usually slides.

This lens has a diameter of a little over 30 millimetres, and, when the wood surface is at a distance of about twelve inches from the iris, gives a distinct micrograph, under low magnification, of a surface of at least three inches on the focusing-screen, at a distance of twenty-six or so inches from the iris.

PRELIMINARIES.—A typical piece of the dressed wood surface is selected, and a series of measurements made to enable the operator to fix the block so that the desired field may be covered by the lens. The log is now securely propped up in position at the necessary distance in front of the lens; and it is important that it be fixed so as to be perfectly immovable, in order that the surface may be and

remain in a plane at right angles to the optic axis of the apparatus. The camera is now extended as far as necessary to produce the required magnification and cover the plate, this distance, of course, varying with the lens used.

FOCUSING.—The Welsbach is turned on, and the first focusing done by means of a ground glass focusing-screen. It will now be seen if the whole of the surface is satisfactory, and if any alteration in the position of the log is deemed necessary to get the best surface in the field, or to get the surface all in the same place at right angles to the optic axis of the apparatus, such alteration is now to be made. A focusing-screen of transparent glass is now substituted for the ground glass one, and the finer focusing is done by means of the special focusing-lens; it is at this point that one regrets any carelessness in the matter of placing the log, either its position or stability. For micrographic work, focusing with the transparent screen is a necessity, and here it must certainly not be omitted, as it is impossible to bring out the fine surface detail without it—the ground glass screen is merely used to ascertain that all is in satisfactory position.

The Welsbach is now turned into the bye-pass, and the magnesium ribbon is lighted, and fed slowly and as steadily as possible through the ribbon tube. While an assistant attends to the lighting, the final focusing for the intense magnesium light is made, and the necessary stop inserted in the lens. A considerable time may profitably be spent in the operation of focusing. I often spend half an hour over it, and thereby save much subsequent disappointment.

THE RADIANT.—This is placed as near the surface as possible, but care has to be taken that the light shall not "flare" the lens. This latter trouble may be obviated by means of a hood of paper or metal painted mat-black placed over, and extending some way out from, the front of the camera towards the surface of the log. This prevents any flaring of the lens, and allows of the illuminant being brought as near as may be desired.

On the average, a distance of eight inches from the light to the illuminated surface was found suitable. In regard to the angle at which the rays of light from the

radiant must fall upon the surface to obtain the best results, one must take into consideration the character as to colour, markings, etc., of the surface. A little experience soon enables the operator to surmount this difficulty. In the case of such surfaces as that of the oak and so forth, which present comparatively well-marked colour contrasts and distinct markings, the best results were got with the incident rays falling on the plane of the surface at an angle of 40 degrees or so. On the other hand, surfaces such as those of beech and birch, etc., with fine lines and markings, require the angle to be somewhat narrowed. Alterations in the incident angle and the distance of the illuminant, require to be made when working with highly-polished surfaces of recent wood or of silicified stems.

I use no condenser for the light. At first I used two bull's-eye condensers in an attempt to parallelise the rays, but discarded both for two reasons: one was the difficulty of ensuring that the unsteady light from the burning ribbon should pass through both lenses and illumine the desired part of the field, and the other was the difficulty of getting a large enough field of light of uniform intensity to cover the surface. I now prefer the simpler method of using the ribbon as near the surface as I can get it, and giving a longer exposure.

Strong objection has been taken to the using magnesium ribbon as an illuminant, because of the difficulty of ensuring a steady and constant light. This difficulty has not made itself very apparent in this method, as the results testify; and this, even with the very long exposures necessary, in which many inches of ribbon were burnt, and the variation in the light must of necessity have been at its maximum.

PLATE AND EXPOSURE.—Each worker has his favourite plate, but after trying a number of different plates of different speeds, I always came back to the Ilford when I wished to be certain of my results. Most of the work was done with Ilford ordinary, but, in some cases, to overcome colour difficulties I used the Isochromatic plates of this maker. As far as my experience goes, a slow plate is to be preferred for this special purpose of opaque wood micrography.

After the final focusing and stopping down of the lens,

the dark slide and plate are inserted in place of the screen, the ribbon lighted and slowly fed through the tube, the shutter drawn, and the plate exposed. Some surfaces require longer than others, but an average exposure of forty seconds was sufficient.

In developing the plates, I use a pyro-soda fluid. It gives a thinner but also cleaner plate than pyro-ammonia—two characters which are not undesirable in this instance.

Should a plate, on development, be found to be over or under-exposed, I prefer to make a fresh exposure, utilising the experience gained from the first failure, rather than waste time "doctoring" the plate, which seldom gives satisfactory results.

Good effects are got with bromide prints, gelatino chloride, and also with sodiotype, which last approaches in colour in some cases the natural tint of the wood.

As a speedy and reliable method of obtaining accurate representation of the diagnostic characters of timber for museum and teaching purposes, for comparative and research work, and also for identification of timber, I find the above all that can be desired. It is specially valuable for teaching purposes, as only the important diagnostic details are brought out to the exclusion of the minor though not less interesting structural characters.

SECOND METHOD.

Photomicrographs of smaller areas of surface under a somewhat higher magnifying power are useful in the comparison and elucidation of points of detail, *e.g.* the sinuous tangential lines of vasa in the autumn wood of *Ulmus*, and the similar lines of parenchyma in corresponding positions in the oak and certain fossil woods, etc.

Such may be obtained by using the microscope with a low-power objective of one, two, or three-inch focus in place of the photographic lens of the first method. In this connection, it is necessary to use a microscope in which the stage and all the usual substage mechanism is removable, so as to allow of the block of wood being brought within focus of the lens. Further, I have found it useful to have a small apparatus with an iris-diaphragm to screw on to the end of the microscope tube behind the objective. Leitz

now supplies an 80 mm. objective containing an iris-diaphragm on the principle of a photographic lens, which suits admirably for this kind of work.

The ocular is removed, and a tube of mat-black paper substituted; the microscope so altered is clamped to the base board, the tube bent over into the horizontal position, and coupled on to the camera, and all the parts thrown backwards so that their ends lie in one vertical plane and allow the block to be brought as near the lens as may be desired.

Illumination, focusing, and exposure are the same as in the first method, but greater care, if possible, is required.

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PLATE.

This is a reproduction of a photograph taken by Method I. of the cross surface of a block of oak wood. The diagnostic points are well brought out, viz. characteristic medullary rays, porous spring zone, radial lines of pores in autumn wood, and tangential lines of parenchyma in the autumn wood of broad rings.

On the Histological Structure of Fossil Woods. Part I. (Abstract). By R. A. Robertson, M.A., B.Sc.

(Read 8th April 1897.)

The history of specimen I. of this series, in the museum of St. Andrews University, has been lost. The stem is silicified, and somewhat weathered on the exterior, and structurally is a very interesting one. One transverse face has been polished, and measures about 5½ inches by 3 inches. The stem has been distorted by pressure in the radial direction, the effects of which are seen in the collapsed vasa, narrowed rings, medullary rays, and wood parenchyma. The pith shows no structure, being merely an amorphous mass of silica. In outline, the section is oblong, with one corner rounded off. On this rounded side, measuring 3½ inches by 1 inch, a few annual rings are preserved intact, showing the diagnostic histological character of the wood.

OAK.

Looked at with the naked eye, the following are the points noticeable:—The *annual rings* are not distinctly marked, still one can make out on the specimen a concentric series of about twelve such growth marks (whether annual rings, so called, or not is an open question). In the uninjured part the ring measures, on the average, 10 mm.,—a very rapid growth if each increment be annual; in the crushed part it is diminished to one-half the size. Each ring appears marked off from its successors by an area devoid of pores.

The *Medullary Rays*.—These appear as sharp white radial lines, running sinuously and continuously through the uninjured part; they can be traced readily through several rings of the crushed part of the stem, despite a certain amount of lateral displacement. The rays visible to the unaided eye are of fairly uniform size, and occur pretty close together.

Pores (*Vasa*).—These are arranged approximately in radial rows, and while all the vasa in any one row are practically visible to the naked eye, these in the first part of each annual ring—"the spring pores"—are characterised by their comparatively large size, in fact the calibre of the pores diminishes as they are traced out radially. Similarly, also, their distribution alters. They are most abundant in the spring, and gradually diminish in numbers as they pass out, until at the limit of each growth-increment occurs an area where they are very scarce and small, or altogether absent.

The next and very interesting point is a series of sinuous or zigzag tangential lines, white in colour, like the rays running concentrically in the yearly increments and producing a series of "spurious rings."

With the naked eye, they are seen to form a series of concentric rings stretching irregularly from vessel to vessel. Sometimes they are continuous across several rays, with a straight or zigzag course, at other times they do not correspond on opposite sides of the same ray. They bifurcate to enclose the smaller vessels or pass on the outer or internal border of the large vessels. While these spurious rings are broader and farther apart in the spring wood, they gradually become narrower and closer approximated outwards to the limit of the "annual ring." An

examination of the crushed part of the stem shows that while the vasa are collapsed, the medullary rays and false rings are reduced to mere white lines. The limit of each annual ring is marked by the close approximation of several of these "false rings."

Microscopic details (see plate p. 54).—In size, the vessels are about the same as those of the palms and cucumbers. In the spring wood, the radial diameter is 0·36 mm., while the tangential diameter is 0·30 mm. Farther out, the vasa diminish in size to $0{\cdot}10 \times 0{\cdot}16$ mm.

The vasa occur singly, but pairs are pretty common—the individuals of each pair are arranged radially with a straight tangential septum, so that each has a plano-convex outline.

Radial triplets, however, occur, the external of the three pores being usually small, and having the appearance of having arisen by a tangential septum having been formed in what was originally at the start a member of a twinned vessel.

The tangential diameter of the vessels is, as a rule, somewhat in excess of the distance separating two adjacent medullary rays, so that where they approximate a vessel the rays are bulged outwards and separated from the vessel by small-celled wood parenchyma.

In some cases the parenchyma has grown into the vessel, giving the well-known thyloses parenchyma common in robinia, oak, etc.

It is interesting also to note that in some vasa appear the remains of what may be fungal mycelium.

Medullary Rays.—In an area of $2\frac{1}{2}$ mm., one counts on an average 15 rays.

The majority are multiseriate, but a few uniseriate rays occur between the broader ones. The large rays are fairly uniform in size, and run very continuously, diverging outwards where they touch a vessel. In many cases they thicken on either side where they are crossed by or come in contact with the false rings. Their breadth varies from ·02 mm. to ·07, and while the smallest consist of a single row of cells, the largest are usually four cells broad.

In their measurements the medullary rays approximate those of some leguminous woods as given in Nördlinger's Tables.

The medullary ray cells are of oblong form, the long axis radial; nothing more can be made out than their form or arrangement, for they are almost amorphous silica and nearly structureless.

The sinuous white bands, or spurious rings, are broad bands of thin walled wood parenchyma—one can just make this out, for, like the rays, they are almost structureless. As to their course, they run concentric to the annual rings, but not continuous for any great distance — crossing the medullary rays and becoming continuous on the other side or stopping short. Tracing one of these bands: it starts from the perivascular parenchyma, stretches across to the next medullary ray, which may thicken somewhat to meet it. Across the ray it may not be continuous, or it may have bifurcated each arm passing on. In this course it may alter its dimensions, broadening out here and thinning out there, and is by no means straight, but a series of zigzag. At the next vessel it may bifurcate and start again on the opposite side as one.

Structurally, they consist of a mosaic of closely packed polygonal cells without intercellular spaces. The cells are large and thin walled, and quite distinguishable from the other wood elements. They are broadest radially in the spring wood, 0·20 mm., and farther apart 0·40 mm. While the largest here consist of 7 to 8 breadths of cells, radially there is great variation even in the same band, sudden thinning being common. At the outer limit of the year's wood, the radial breadth of the band is 0·12 mm., and they are separated by a distance of 0·14 mm.

This metatracheal parenchyma and the medullary rays conjointly divide the wood into a series of what are *oblong or square areas.* These last are largest in spring, and smallest in autumn wood.

The bulk of each area is composed of woody fibres, with very thick walls, so much so that in some cases the lumen is almost obliterated. Around these, and separating it from the rays on the radial sides and the false rings on the tangential side, is a single layer of thin-walled cells, which appear to be fibrous parenchyma. Occasionally the whole square appears composed of this last.

Systematic Position.—The points of special importance to

be kept in view in an attempt to locate this wood in its systematic position are—the pores, rays, indistinct rings, and especially "spurious rings" of soft tissue. Somewhat similar rings occur in a few British woods, but there the tissue forming the rings is of different histological structure, or is differently arranged. The indistinctly marked "annual ring" is an attribute of tropical rather than of temperate wood. Spurious rings, as seen in the fossil, are of common occurrence in tropical trees, and have been used as diagnostic characters in the classification of such timber, and in the identification of even families and genera.

They occur in the wood of species of Anonaceæ, Sapotaceæ, and Ebenaceæ. They are very common in tropical Leguminosæ; occur also in Guttiferæ, Celastraceæ, Meliaceæ, Boragineæ, and Urticaceæ.

Recent woods, showing structural peculiarities most closely identical with those of the stem described, are found in the orders—Leguminosæ, Urticaceæ, Sterculiaceæ, Combretaceæ, and Boragineæ, the genus *Cordia* of the last-named order presenting woods of very similar character, while the tropical woods of the four first-mentioned are distinguished by slight differences in the medullary rays and the distribution of the pores.

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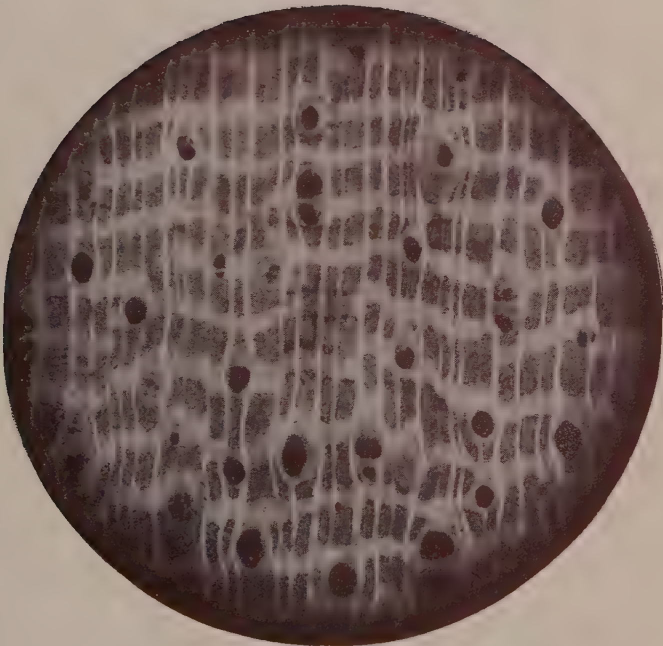
PLATE.

Reproduction of a photomicrograph of the surface of fossil, taken with 1 inch objective by Method II., described on page 49.

A METHOD OF INJECTION-STAINING PLANT VASCULAR SYSTEMS. By R. A. ROBERTSON, M.A., B.Sc.

(Read 8th April 1897.)

There is the well-known method of Von Höhnel (Pringsheim's Jahrbücher, xii., 1879, p. 47) of taking advantage of the negative pressure of a strongly transpiring branch or shoot. The vessels of such a branch, if cut



FOSSIL WOOD.

under a stain, as eosin, will be found injected to a considerable distance. There is also a method of injection by means of the filter pump (Darwin's Physiology of Plants, p. 87). But there are many specimens which do not lend themselves to injection by either of these methods. I find the following simple method extremely useful both for class purposes and for private work. The apparatus once set agoing requires little attention, and a large number of specimens for laboratory work may be injected in succession in a short time with a minimum amount of trouble. I submit a few sections of stems injection-stained by this method, to show the amount of penetration it is capable of giving.* The practical worker will, however, find it useful for all kinds of plant members.

To the end of a large glass funnel a length of india-rubber tubing is securely wired. The funnel is fixed at a convenient height, and the lower end hangs free eight feet or more in length; at the lower end is fixed a compressor clip. The stem, air-dried (I show an Aspidium stem injected after lying in laboratory for years), preserved in spirit, or fresh (perhaps in many cases preferably the latter), has its end cut smooth and circular, and securely wired into the lower free end of the tube. In the case of delicate stems, it is preferable to lute with Canada balsam or asphalt to avoid crushing. A beaker is placed beneath to catch the escaping fluid. The funnel and tube are now filled with a weak aqueous solution of fuchsin, the compressor clip removed, and the stem left to itself for a few hours. At the end of that interval it will be found that a considerable quantity of the stain has passed through the conducting elements, staining them *en route*. One advantage of using the living stem is that the stain is pretty well confined to the conducting elements, and hence a good differentiation staining may afterwards be obtained. The compressor clip is again applied, and the stem removed and transferred to a duplicate tube containing a solution of weak picric acid. This washes out the stain held in the conducting elements by capillarity, and darkens the stained elements, and at the same time fixes the tissues.

* Aspidium stem (air-dried); Cycas stem (fresh); Dracæna (spirit material).

When the picric acid comes through clear, the stem is ready for the next part of the process. It is removed, and, if intended for sectioning purposes, is cut up into small pieces and placed in alcohol of at least 90 per cent. strength. In this it is decolorised, and after a few days is in good condition for sectioning purposes. The liquified elements of the conducting system are stained a fine pink. A good contrast is obtained by ground staining with hæmatoxylin on the slide. If the stem be intended for dissection of vascular system, the picric injection may be omitted and the preparation allowed to lie for a time in weak picric acid, and then preserved in alcohol until required.

PYRUS ARIA AND ITS VARIETIES IN ARRAN.

By Rev. DAVID LANDSBOROUGH.

(Read 8th July 1897.)

I know the island of Arran well, and it seemed to me strange that its Rare Pyrus should be confined to a small portion of the north. There are places in other parts of the island seemingly suitable for its growth. Might it not also be found in some of these? I determined to search Arran for it. I wished, further, to ascertain if it could not be had in additional varieties; and if the varieties were accidental, or resulted from discoverable causes. This led to several excursions. I mention the principal:—

UNSUCCESSFUL EXCURSIONS.

First.—At the end of May, with one of my sons, I started from Brodick, in the centre of the east coast: went up Glen Rosa to the Garbh Allt ($2\frac{1}{2}$ miles); ascended this stream; descended into Glen Iorsa; forded it; ascended the connecting stream to Loch Tana; thence to Loch Dubh; descended Glen Schaftigill; passed into Allt-na-h-Airidhe; descended to Dougrie; thence to Shedog Inn.—Twelve hours afoot.—No success.

Second Excursion.—Next day we took, for four miles, the road to Brodick; at Glen Loig, turned up the Craigan, the most considerable glen running southward through the

centre of the island; examined it and its tributaries; crossed the highway between Lamlash and Lag at its saddle; ascended to Loch Urie; descended by the Knockenkelly Glen to Whiting Bay; thence to Kildonan—13¼ hours.—No success, save finding a magnificent plant of the Guelder Rose (*Viburnum Opulus*) overhanging a waterfall in Craigan Glen.

Third Excursion.—With the Rev. Robert Drummond, Lothian Road, Edinburgh. From Lochranza, in the north of Arran, we passed along the hillside southward, visiting the Fairy Dell and the Great Rent, the latter about 950 feet above the sea, and nearly forty feet in depth (recognisable by a mountain ash growing at its entrance); descended at the Old Salt Pans; advanced to Lagan, famous for its fossil beds; ended at Corrie.—No success.

Fourth, Fifth, and Sixth Excursions.—Visited North Glen Sannox; ascended its greatest gorge to the east shoulder of the first of the high Sannox range (*Suidhe Fheargnas*); passed by it into South Glen Sannox. Visited the glens and gorges on the side of Glen Sannox, and also those above Corrie to Maol Donn — half-way to Brodick. Ascended the gorges on both sides of Glen Chalmadale. —No success.

SUCCESSFUL EXCURSIONS.

First Successful Excursion.—Having been unsuccessful in south, east, and west, both in the centre of the island and by the coast, I drew nearer the already-known habitats of the Rare Pyrus. Having landed by the Fairlie and Campbeltown steamer at Pirn Mill, six miles south of Lochranza, I ascended the Allt Gobhlach to the beautiful little waterfall (The Raven's Nest), two or three hundred feet above sea-level. Above this the botanical feature of the stream is the abundance of the aspen (*Populus tremula*). This was a good omen, as a plant of it grows with the Rare Pyrus in the tributary at the head of Glen Catacol. From the Allt Gobhlach stream I passed by the south shoulder of Beinn Bharain to Loch Dubh. In it I found *Lobelia Dortmanna* and *Utricularia vulgaris*, both of which grow also in Loch Tana and in Loch-na-Davie (1182 feet above sea-level).

A Striking Peculiarity.—Loch Dubh is a quarter of a mile in length and is about twelve hundred feet above sea-level. It is situated on the shoulder of Beinn Bharain, and must receive a very copious supply of water, yet in the map of the Ordnance Survey no outlet is assigned it. At the northern extremity there is the bed of a stream leading to Loch Tana, yet, though there had been considerable rain recently, in the upper portion there was no water, though there was abundant evidence that at times in it there is the rush of a torrent. The explanation must be that the basin and sides of the loch are so gravelly that in ordinary weather the water finds through them sufficient exit.

I now passed to Loch Tana (the Long Loch) and thence directed my course eastward.

Mr. Smith, Monkredding, Kilwinning, in a remarkable paper, entitled "New View of the Arran Granite Mountains," read March 1895 to the Glasgow Geological Society, and since printed, writes: "The Allt-an-Champ (the Camp Burn) gets its name from an old practice of the natives to camp here with their cattle during summer, and remains (traces) of their huts are still to be seen. It presents us at one part with a little glen cut in the solid rock to a depth of perhaps twenty feet. Growing out of a joint of the granite and overhanging the glen is a much-branched specimen of *Pyrus aria*, rare in this country. This is one of the few trees in the granitic area, and has not escaped the notice of the natives, who have a tradition that 'once upon a time a strange bird brought a seed and planted it here, and out of the seed grew this tree.'" The Allt-an-Champ is a western tributary of the Iorsa and joins it 2½ miles south of Loch-na-Davie. Guided by Mr. Smith's interesting statement, and with the hope that the plant he mentions might not be a solitary example, I struck this stream half-way up and followed it up and down. I was successful, as I found several of the rare tree. I now pushed on by Loch-na-Davie to Corrie.—Eleven hours.

Second Successful Excursion.—When visiting, on former occasions, the head of Glen Catacol at its eastern division, where the Rare Pyrus has long been known to grow, I had noticed the steep gorge here ascending from its left

side, and thought it also a likely habitat for the Rare Pyrus, all the more that a young plant grows near its junction with the stream. I determined to examine it. I was rewarded by finding the Rare Pyrus in considerable abundance. One of the plants, of the intermediate type, had the largest leaves I had yet noticed in any of the varieties—one, not including stalk, $5 \times 3\frac{1}{4}$ inches. Here also I found a specimen of *Sedum Telephium*. I passed over the ridge, and descended the gorge on the opposite side. Great abundance in it of *Pyrus Aucuparia*, and of the Aspen; but none of the Rare Pyrus.

Third Successful Excursion.—At the mouth of Glen Catacol is an amphitheatre of level ground, with a radius of half a mile. It has evidently been formed by detritus brought by the stream. In addition to the Catacol, four little torrents flow into it. The course of the two on the south side I examined without success. So also on the north, the Abhain Bheag (the Little Stream). But at the north-east corner is the Uisge Solus (the Water of Light, *i.e.* the Sparkling Water). This is a remarkable stream. It is a main stream, and not a tributary. It comes down the side of a high steep, leaping and dancing in many a foamy fall, resembling the White Water at Corrie, only the falls more numerous and the body of water less. It was not likely to have on its banks the Rare Pyrus, as it was near the sea, and the rock was slate, while this Pyrus had hitherto been found only in the granite, and at a distance from the sea. The stream, however, was inviting, and I ascended. I had gone only half a mile (afterwards measured), and to the height of 400 feet, when, on passing a little sheep bridge, I came upon the Rare Pyrus, which continued at intervals till the bare moorland was almost reached. A number of things were notable. (1st) There was good shelter, for it was a cross stream, that is, a tributary, and thus not exposed to the tremendous blasts which render tree-life almost impossible in the great glens. (2nd) The stream abounded in little waterfalls, presenting specially cosy nooks. (3rd) The rock is contorted schist, "gnarled and twisted, with many minute cross grains" (Smith), which decomposes into a soil specially suitable for nourishing plants, while its many crevices provide

abundant hold for their roots. (4th) There is here a rare union of flora—Hawthorn (long stemmed and very narrow leaves), Honeysuckle, Scotch Rose, Juniper, Lycopodium, the Common Butterwort and the rare Seaside Butterwort (*Pinquicula lusitanica*), the Red Bearberry, this Rare Pyrus, Birch, Rowan, etc. (5th) The Rare Pyrus was all of one variety, the pinnate. It was the most pinnate I had seen in Arran, generally three of the lower segments cut to the mid-rib, while in those found at other stations rarely are even two of the lower segments thus deeply cut. (6th) This station is further remarkable as being situated in the slate, while all the others are in the granite; and also from being near the sea, only three-quarters of a mile from it, while those known previously are from $2\frac{1}{2}$ to 6.

The discovery of this station is thus of special importance, as it introduces new data into the questions regarding the Rare Pyrus.

Fourth Successful Excursion.—The Rev. Duncan M'Nicol, Dunoon, informed me that the Rare Pyrus grew at the stream side, near the foot of the steep ascent at the head of Glen Catacol. I visited the place and found a considerable number. I ascended here Allt-na-Calmen (the Dove's Glen-side Stream), the highest tributary of the Catacol. In it are various cascades, and beside them are a dozen of the Rare Pyrus. The peculiarity here is that it is much more common than the Rowan, of which there is only one tree standing.

SUMMARY.

I. By Mr. Smith's discovery and my own, the number of main streams in which the Rare Pyrus is known to grow has been doubled—from two to four.

II. By Mr. Smith's discovery and my further search, it has been shown that the Rare Pyrus is not confined to the north of the dividing ridge in the north of Arran—that is, to the north of Loch-na-Davie and Loch Tana—but has an established habitat several miles south of this ridge.

III. It has been shown that it is not confined to the granite area, nor to a distance from the coast-line.

IV. Its range in altitude has also been increased It

is from 300 feet in the Iorsa tributary, to 1100 feet on the north side of the range of North Sannox.

V. There are three varieties in Arran—(1st) the leaf narrow, little cut, very white, downy underneath, and slightly downy on the upper side; this is by much the most rare: (2nd) that which has the largest leaf, not so downy as the previous, pinnatifid, but seldom pinnate, running however into the third: (3rd) the three lower segments of the leaf generally pinnate.

VI. That the trees in the little stream at Catacol, where there is proximity to the sea and the rock—not granite, but a slate—are all of the third variety.

VII. The form of the tree conforms to the shape of the leaf. This is very notable in the first variety. In it the leaf being narrow, the branches and twigs are slender and drooping.

VIII. The bloom of all is fragrant.

IX. The range of the Rare Pyrus in Arran corresponds to that of the Red-berried Bearberry (*Arctostaphylus Uva-Ursi*). This plant had previously been noted in the Holy Isle. The writer was the first to notice it in Arran proper. He now adds that he has found it in the neighbourhood of all the habitats of the Rare Pyrus, and that he does not know of it being found elsewhere in Arran.

X. The known stations of the Rare Pyrus in Arran are—(1st) the Allt-an-Champ, a tributary of the Iorsa, fully two miles south of Loch-na-Davie; (2nd) a stream on the northern slope, at the head of the North Sannox range; (3rd) the three streams into which the Easan Biorach divides at the foot of the steep slope to Loch-na-Davie, that on the east being the lower part of the same stream mentioned in number 2; (4th) the stream (not a tributary) at the mouth of the Catacol; (5th) the eastern head of the Catacol; (6th) the eastern tributary to it; (7th) the head of the Catacol; (8th) Allt-na-Calmen, the Catacol's highest tributary—ten stations in all.

XI. In a letter to Professor Balfour, of which he was so kind as send me a copy, Professor Koehne, of Berlin, writes: "Messrs. Ley and Landsborough, if they search more carefully, will find forms of the Rare Arran Pyrus, scarcely to be distinguished from *Sorbus Aucuparia*, since they have

completely pinnate leaves, the upper leaves, however, a little decurrent on the mid-rib of the compound leaf, or are slightly fused together."

To some extent this has been realised, but the belief of the writer is that no more careful search in the formerly known habitats would have so resulted. It is entirely owing to the discovery of the new habitat in slate rock, and near the sea, in the Uisge Solus, at the mouth of Glen Catacol.

I send leaves of (1st) *the narrow-leaved variety*, gathered from a tree on the west tributary at the head of Easan Biorach (Lochranza Stream); (2nd) *the intermediate variety*, from the tributary stream to the eastern head-water of the Catacol; (3rd) the Pinnate variety, from the Uisge Solus.

I forward, also, the Ordnance Survey map of the north of Arran, on which I have encircled in red the area in which the Rare Pyrus has been found.

Notes on Gleichenias. By Percival C. Waite.

(Read 12th April 1894.)

The following is an abstract of the chief characteristics which I have observed:—

I. In the *Mertensias* the bundle of the petiole, as seen in T.S., is curved into a $\cup$ shape; in the *Engleichenias* the arms of the bundle unite, so that the cortex embraced by them, together with the portion of bundle-sheath which separates the cortex from the bundle, is nipped off. We have thus an annular bundle surrounded by its bundle-sheath, and containing within it a portion of the outer cortex with a few cells of the bundle-sheath surrounding it. This is the case in the young petiole; later on this inner patch of cortex disappears.

That this peculiar arrangement of the bundle is developed in the way above described may be proved by examining the petiole of the *Engleichenias*, at different levels, as it emerges from the rhizome, where transition stages may be observed. There is first a stage resembling the arrangement in the *Mertensias*, then a little higher up

the approach of the arms cutting through the neck of cortex which joins that inside to the surrounding mass, and, finally, the disappearance of this central portion of cortex and inner ring of bundle-sheath.

II. The bundle-sheath in the petiole and rhizome does not appear as a cortical layer similar to the bundle-sheath (endodermis) of roots, since the cortical cells do not lie opposite the cells of the bundle-sheath, but seem to form part of the bundle itself; it, however, shows the characters of the typical endodermis, with dark dots on the radial walls, and no intercellular spaces. The inner layer of the cortex is not differentiated from the other cortical layers.

III. The layers of cells internal to the bundle-sheath are derived from it by division of its cells, and these divisions begin at a short distance below the apex, but do not form a pericycle.

IV. The spore of the *Mertensias* is reniform; round and marked with a triradiate line in the *Engleichenias*.

I consider that the differences in spores, petiolar bundles, general growth and appearance of the plants, justify the greater distinction formerly made between the *Mertensias* and *Engleichenias*, when they were considered as different genera, and that these characters are sufficient to prevent the two genera being classified as merely sections of one genus.

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TRANSACTIONS AND PROCEEDINGS

OF THE

BOTANICAL SOCIETY OF EDINBURGH.

SESSION LXII.

MEETING OF THE SOCIETY, November 11, 1897.

Dr. A. P. AITKEN, President, in the Chair.

The following Officers of the Society were elected for the Session 1897–98:—

PRESIDENT.

WILLIAM WATSON, M.D.

VICE-PRESIDENTS.

J. RUTHERFORD HILL.
Captain F. M. NORMAN, R.N.
ANDREW SEMPLE, M.D., F.R.C.S.E.
ROBERT TURNBULL, B.Sc.

COUNCILLORS.

Colonel FRED. BAILEY, R.E.
W. BONNAR.
WILLIAM CRAIG, M.D., F.R.S.E., F.R.C.S.E.
W. CALDWELL CRAWFORD.
ARTHUR E. DAVIS, Ph.D., F.L.S.
T. CUTHBERT DAY.
Professor COSSAR EWART, M.D., F.R.SS. L. & E.
SYMINGTON GRIEVE.
Rev. DAVID PAUL, M.A., LL.D.
T. BOND SPRAGUE, M.A., LL.D., F.R.S.E.

Honorary Secretary—Professor Sir DOUGLAS MACLAGAN, M.D., LL.D., *Ex-P.*R.S.E.
Honorary Curator—The PROFESSOR OF BOTANY.
Foreign Secretary—ANDREW P. AITKEN, M.A., D.Sc., F.R.S.E.
Treasurer—RICHARD BROWN, C.A.
Assistant Secretary—JAMES ADAM TERRAS, B.Sc.
Artist—FRANCIS M. CAIRD, M.B., C.M., F.R.C.S.E.
Auditor—ROBERT C. MILLAR, C.A.

Issued November 1898.

LOCAL SECRETARIES.

Aberdeen—Professor J. W. H. Trail, M.A., M.D., F.L.S.
Bathgate—Robert Kirk, M.D., C.M., F.R.C.S.E.
Beckenham, Kent—A. D. Webster.
Berwick-on-Tweed—Francis M. Norman, R.N.
Birmingham—George A. Panton, F.R.S.E., 73 Westfield Road.
,, W. H. Wilkinson, F.L.S., F.R.M.S., Manor Hill, Sutton Coldfield.
Bridge of Allan—Alexander Paterson, M.D.
Bromley, Kent—D. T. Playfair, M.D., C.M.
Calcutta—George King, M.D., F.R.S., Botanic Garden.
,, David Prain, M.D., F.R.S.E., F.L.S., Botanic Garden.
Cambridge—Arthur Evans, M.A.
Chirnside—Charles Stuart, M.D.
Croydon—A. Bennett, F.L.S.
Dehra-dun, India—James Sykes Gamble, M.A.
Dundee—Professor P. Geddes, F.R.S.E.
Glasgow—Professor F. O. Bower, Sc.D., F.R.S., F.L.S.
,, Professor J. Cleland, M.D., F.R.S.
,, Professor Scott-Elliot, F.L.S.
Kelso—Rev. George Gunn, M.A., Stitchel Manse.
Kilbarchan—Rev. G. Alison.
Lincoln—George May Lowe, M.D., C.M.
London—William Carruthers, F.R.S., F.L.S.
,, E. M. Holmes, F.L.S., F.R.H.S.
,, John Archibald, M.D., F.R.S.E.
Melrose—W. B. Boyd, of Faldonside.
Otago, New Zealand—Professor James Gow Black, D.Sc., University.
Oxford—Dr. Gustav Mann.
Perth—Sir Robert Pullar, F.R.S.E.
Philadelphia, U.S.A.—Professor John M. Macfarlane, D.Sc., F.R.S.E.
Saharunpore, India—J. F. Duthie, B.A., F.L.S.
St. Andrews—Professor M'Intosh, M.D., LL.D., F.R.SS. L. & E.
,, Robert A. Robertson, M.A., B.Sc.
,, Dr. J. H. Wilson.
Toronto, Ontario—W. R. Riddell, B.Sc., B.A.
,, ,, Professor Ramsey Wright, M.A., B.Sc.
Wellington, New Zealand—Sir James Hector, M.D., K.C.M.G., F.R.SS. L. & E.
Wolverhampton—John Fraser, M.A., M.D.

The TREASURER submitted the following Statement of Accounts for the Session 1896–97 :—

INCOME.

	£	s.	d.
Annual Subscriptions, 1896–97; 60 at 15s. = £45, and 1 at 10s.	£45	10	0
Do., 1895–96, 4 at 15s.	3	0	0
Compositions for Life Membership	11	11	0
Transactions, etc., sold	4	1	0
Subscriptions to Illustration Fund	3	10	0
Interest on Deposits in Bank	1	19	1
	£69	11	1

EXPENDITURE.

	£	s.	d.
Printing *Transactions*, £18, 13s. 2d.; Billets, etc., £8, 3s. 6d.	£26	16	8
Rooms for Meetings, Tea, and Hire of Screens	6	6	2
Stationery, Postages, Carriages, etc.	4	12	3
Fire Insurance on Books, etc.	0	5	0
Expenditure	£38	0	1
Balance of Income	31	11	0
	£69	11	1

STATE OF FUNDS.

	£	s.	d.	£	s.	d.
Amount of Funds at close of Session 1895–96				£62	8	4
Add—Increase during Session 1896–97, as above				31	11	0
Amount of Funds at close of Session 1896–97				£93	19	4
Being:—Sum in Current Account with Union Bank of Scotland Ltd.	£30	7	4			
Sum in Deposit Receipt with do.	90	0	0			
Due by Treasurer	0	8	8			
	£120	16	0			
Deduct—Account not paid till after close of Session	26	16	8			
				93	19	4

Note.—Subscriptions in arrear, 1895–96, £1, 10s.; 1896–97, £6, 15s.

On the motion of Dr. William Craig the report was adopted and the Treasurer thanked for his services.

The Presidential address for the Session was read by Dr. A. P. Aitken.

Meeting of the Society, December 9, 1897.

Dr. William Watson, President, in the Chair.

A communication on the Measurement of Girth of Coniferous Wood at Braemar was read by Messrs. Turnbull and Waite.

A paper on a Comparison of Plants with Animals was read by the President.

Meeting of the Society, January 13, 1898.

Dr. William Watson, President, in the Chair.

The Laws of the Society were signed by Mr. F. C. Crawford.

A further communication on the Increment of Girth of Coniferous Trees at Braemar was read by Mr. Robert Turnbull, B.Sc.

The report of the Scottish Alpine Botanical Club's Excursion to Killin was read by Dr. William Craig.

MEETING OF THE SOCIETY, February 10, 1898.

Dr. WILLIAM WATSON, President, in the Chair.

Miss R. ORROCK was proposed as a Resident Fellow of the Society by Mr. ROBERT TURNBULL, B.Sc., seconded by Dr. WILLIAM WATSON.

Mr. DUNN, of Dalkeith, exhibited a number of plants in flower in the open air, as illustrating the mildness of the season.

A paper on the Changes which take place in the Nucleus of Secreting Cells was read by Miss L. H. HUIE.

Two caterpillars, infested with *Cordyceps Militaris*, from India, were exhibited by Miss ORROCK.

MEETING OF THE SOCIETY, March 10, 1898.

Dr. ANDREW SEMPLE, Vice-President, in the Chair.

Miss R. ORROCK, proposed by Mr. ROBERT TURNBULL, B.Sc., seconded by Dr. WM. WATSON, was balloted for and duly elected a Resident Fellow of the Society.

A communication on *Apodya lactea* was read by Mr ROBERT TURNBULL, B.Sc., and was illustrated by means of the lantern.

A communication on the Colour of Daffodils in relation to the Character of the Soil on which they grow was read by Dr. A. P. AITKEN.

Meeting of the Society, April 10, 1898.

Mr. J. Rutherford Hill, Vice-President, in the Chair.

A Herbarium of the rarer Alpine Plants collected in the neighbourhood of Braemar in 1854–55 by the late A. Croall, Esq., was exhibited by Mr. Robert Turnbull, B.Sc.

Mr. Turnbull communicated a paper on the Flora of Franz-Josef Land, and exhibited a number of specimens collected by Mr. W. S. Bruce, Naturalist to the Jackson-Harmsworth Polar Expedition.

Mr. J. Rutherford Hill read a paper on the Alkaloids of *Cephaëlis Ipecacuanha*, and exhibited a number of specimens.

Mr. J. Rutherford Hill read a paper on the Insecticidal Properties of the Flower Heads of *Pyrethrum roseum*, *P. carneum*, and *P. cinerariæfolium*.

Specimens of Douglas Fir attacked by *Phoma pithya* were exhibited to the Society by Mr. Malcolm Dunn, of Dalkeith.

Meeting of the Society, May 12, 1898.

Dr. William Watson, President, in the Chair.

David Russell, Esq., 7 Strathearn Road, was proposed a Resident Fellow of the Society by Miss R. Orrock, and seconded by Mr. Robert Turnbull, B.Sc.

A note on the Hybridisation of Violets was read by Mr. J. Grieve, who also exhibited a number of illustrative specimens.

Meeting of the Society, June 9, 1898.

Dr. William Craig in the Chair.

David Russell, Esq., 7 Strathearn Road, proposed a Resident Fellow of the Society by Miss R. Orrock, and seconded by Mr. Robert Turnbull, B.Sc., was balloted for and duly elected.

Several specimens of *Cuscuta Epithymum* were exhibited by Miss Orrock.

Meeting of the Society, July 14, 1898.

Dr. William Watson, President, in the Chair.

Mr. Pantling, of the Royal Botanic Garden, Calcutta, was duly balloted for and elected an Associate of the Society.

A communication on the discovery of a White variety of *Astragalus alpinus*, Linn., on Ben Vrackie, Perthshire, was read to the Society, and specimens of the plant were exhibited by Mr. Robert Lindsay.

Mr. Robert Lindsay also exhibited, in flower, specimens of a hybrid shrubby Veronica.

TRANSACTIONS AND PROCEEDINGS

OF THE

BOTANICAL SOCIETY OF EDINBURGH.

SESSION LXII.

ADDRESS DELIVERED AT THE OPENING OF THE SESSION BY Professor A. P. AITKEN, M.A., D.Sc., President of the Society.—11th November 1897.

At the meeting of the Society at this time last year I chose as the subject of my address "The Nitrogenous Food of Plants," for the reason that it was a subject in itself interesting, and on which our knowledge was being rapidly developed, and also because, in treating it from a historical point of view, I might prepare the way for other papers of a practical kind on that subject that were to be read before the Society.

The attention of the fellows was chiefly directed to the somewhat recent discovery that leguminous plants, and more especially those of the sub-order Papilionaceæ, possessed, in a remarkable manner, the power of assimilating the free nitrogen of the air and of converting it into their own albuminoid tissue. The interest attached to this discovery was greatly enhanced from two causes—first, because authorities of the highest repute in the domains of botany, chemistry, and agriculture, had, after what seemed to be satisfactory and complete investigation, considered that they were warranted in making the pronouncement that plants did not possess that power; and in the second place, that when, after fifty years' negation, it was at length put beyond doubt that leguminous plants did possess that power, it was shown, at the same time, that they possessed it, not in themselves, but only when their life were

associated with the life of an exceedingly minute organism affecting their roots, causing the development thereon of nodules, in which they lived and brought about changes that were favourable to the growth of their host.

Instances in which two distinct organisms, each living its own life, are associated together for their mutual advantage, are not infrequent in the animal world, and the word *Symbiosis* has been coined by De Barry to express that relationship. The classical researches of Darwin have familiarised us with instances of symbiosis between animals and vegetables, and have shown, with great wealth of illustration, how much plants are dependent on insects for their cross fertilisation, and how whole species of plants may be dependent for their existence upon the regular and unfailing visitation of insects, and, on the other hand, how certain species of insects are dependent on certain species of plants for their food, which they obtain from no other source. The visits of a determinate species of insect to a certain species of plant may be without any benefit whatever to the plant. In that case, the relation of the insect to the plant is simply that of a parasite feeding on food provided by another, and giving nothing in exchange, and in abstracting its food from its host, it may not only do it some injury, but may even injure it so far as to kill it outright. The various species of aphides are an example of that kind. They are very numerous, and exhibit very distinct characteristics according to the kind of plant on which they feed. In how far species of aphis which are found constantly associated with one genus of plants could accommodate themselves to, and find means of subsistence upon, other genera I do not know, but the probability is that in few cases could the parasite subsist under the altered conditions. In such a case the insect has some modification of structure or of function suited to the particular genus on which it lives; but what we require to find in a case of symbiosis is, that the plant also has acquired a modification of structure suited to the characteristics of the insect which feeds on it. What we fail to find in pure parasitism is mutual adaptation, with the ultimate result of mutual advantage. Darwin and others after him have shown how the forms of flowers in some

species have been modified to suit the convenience of their insect visitors, and how the colour had been acquired to allure them; but in such cases the object of the insect's visit, so far as it was concerned, was entirely to satisfy its own wants, yet, in so doing, it ministered unconsciously to the welfare of the plant it visited. Instances of such mutually advantageous connection between plants and insects are numerous, but cases in which plants of widely different order have been found to live in symbiosis with each other are, so far as I am aware, of rare occurrence. There are, however, two very notable instances of plant symbiosis which I would take the opportunity of referring to, though they are probably familiar to all who are here present.

In examining under the microscope the substance of lichens, such as those to which old wayside walls owe their beauty and colour, it is noticed that, while the moss of the structure is composed of a fungus-like arrangement of tissue, having a mycelium whose long hyphæ form a vegetative network over the stone, penetrating its fine crevices, and, while there are disposed on some part of the organism the ordinary fungoid organs of reproduction, there are also to be found, entangled or entrapped within the body of the lichen, a number of little green-coloured cells, which in botanical treatises were called gonidia, and whose object in the economy of the lichen and connection therewith were not understood. But for the presence of these green-coloured cells, the plant would probably have been called a fungus. It was not until a few years ago that Schwendener, from a careful study of the matter, came to the conclusion that what were described as lichens were not a distinct class of plant at all, but really a copartnery of two quite distinct organisms—a fungus and an alga. A fungus is a plant which, however varied its form and habit may be, is distinguished by one characteristic peculiarity, that it cannot make its own organic matter, but can only vegetate upon the organic matter made for it by other plants. On a bare wall a lichen cannot find that organic matter, for no vegetable organisms preceding it in time have left behind them residues in the form of organic matter sufficient for its needs. The only way in which a lichen can grow in

such circumstances is by getting into co-operation with a plant that can make organic matter. Algæ are the most convenient plants of that kind. They are provided with chlorophyll, and in their chlorophyll cells proceeds the wonderful process by which the carbon derived from the carbonic acid of the air is assimilated so as to form sugar, starch, and cellulose, and other organic matters. The small green-coloured cells enfolded in the fungus substance of the lichen are unicellular algæ, which have been caught by it in some way. They have no roots, and are unprovided with the means of obtaining their mineral requirements from the soil. Thus we see in the lichen two distinct vegetable organisms closely associated for their mutual benefit—a fungus, whose mycelium, acting the part of roots, can find on the barest stone the mineral constituents necessary for plant growth, and an alga possessed of the power of obtaining from the air the carbon required to build up the organic tissues of the plant.

That the lichen is really a composite plant of that kind has been proved in a very interesting way. Rees and Stahl chose fungi of various kinds, and also algæ of various kinds, and by bringing them together brought about the conditions of lichens quite similar to known species, and by bringing together a species of lichen and a species of alga that had not been seen associated together before, they were able to manufacture what would have been called a new species of lichen. In course of time the fungus, having grown and flourished, and developed its organs of reproduction and produced a large number of fertilised spores, which are its seed, disintegrates and sets free the unicellular algæ, which on their part have increased in number, and the two kinds of organisms are now ready to be blown away by the wind or carried away by water, and enabled to propagate a new generation of fungi and a new generation of algæ capable of leading single lives in suitable circumstances, or of getting into symbiotic relationship of a similar, or it may be of a quite different, kind from that under which they had been nurtured.

The second instance of plant symbiosis to which I would shortly refer, is one which is not only interesting, but of far-reaching importance.

In 1885 Professor Frank published in the "Berichte der Deutschen Botanischen Gesellschaft" a remarkable paper, explaining in a quite unexpected manner the meaning of the fungoid mantle which had been noticed in the fine roots of the Scots fir, *Pinus sylvestris*, a few years previously by Rees.

He found that not only in the case of the Scots fir, but also in the case of other conifers, and also most markedly in the case of the Cupuliferæ, such as beech and the hazel, the finer and trophic roots were thickly enveloped in the mycelium of a fungus. The constant occurrence of this fungoid envelope on the roots of all the trees of these orders persuaded him that it could not be an accident, and as he found that it existed on the roots of even the youngest and healthiest specimens, he felt satisfied that it could not be a parasite, or at least a destructive parasite. He at once conceived the idea that this was a case of symbiosis, and worked diligently at the investigation of the roots of a great variety of plants from that standpoint. Among these were roots that had been sent to him from all quarters of the globe, and its presence in them all showed that the fungus was universally distributed. This fungus, like others, lives upon organic matter provided for it by other plants. It is found as a fine thread-like mycelium ramifying through the mass of organic matter left by the fallen leaves and débris of forest trees, and is not met with where that organic matter is wanting. When a conifer or cupulifer is planted in such soil, it is not long before its roots are fastened upon by this fungus, and in time the growing points of the roots become closely wrapped round with it. In ordinary circumstances the growing rootlets of plants are beset with fine hairs, through whose delicate walls the nutritive mineral matter in an available soluble form passes from the soil into the circulation of the plant. In the case of the two orders referred to, when the fungus has established itself, the trophic rootlets have no hairs. Their place is taken by the fungus, from which proceed numerous fine filaments, that at first sight might be mistaken for hairs, but which, on microscopic examination, are seen to be aggregated mycelium filaments. That these

filaments take upon themselves the office of roots he could not doubt, for owing to their universal distribution all over the growing root system of the plant, and the entire suppression of the root hairs, there was no other way in which the trees could obtain soil nourishment. It would thus seem that the fungus acted towards the tree the part of a nurse. Its delicate filaments, ramifying through the mass of organic débris, absorbed the nutritive matter found there ready made, and poured it into the roots of the trees. If that is a true account of what takes place in the nourishment of forest trees, it must be regarded as revolutionising our views regarding the physiology of plant nutrition. If the mineral food which these trees require is supplied to them by the organic sap of the fungus, it must be supplied in some form of organic combination, and in that case the trees must owe, not only their mineral, but also some of their organic constituents to the fungus that feeds them. Before the days of Liebig, that is to say during last century and a considerable part of this one, it was universally believed that plants obtained their organic matter from the soil, and humus was regarded as the one essential of fertility. The accumulation of humus in the soil was the aim the cultivator of the soil had before him; and when we consider that it was the leading principle guiding the most intelligent farmers in their operations for centuries, there must have been, and there must still be, a good deal of permanent truth in it.

It was Liebig's greatest achievement to fight against and completely demolish this view, and cause it to be superseded by what was called by him the mineral theory of plant nutrition. This theory established, on the firm basis of actual experiment, the fact that plants did not require to be supplied with organic matter, that, on the contrary, it was the great function of their life to manufacture organic matter; and perfectly unexceptional experiments were carried out in which the plants of our ordinary field crops, chiefly cereals, were grown both in aqueous solutions and in mere sand containing no organic matter whatever, but only solutions of certain salts containing the mineral nourishment that the plants required. The organic matter of plants was proved to be made in their leaves, while the

mineral matters required to enable the leaves to make this organic matter was abstracted from the soil by the roots. It cannot be doubted, for a vast mass of experimental evidence is at hand to prove it, that that describes what is in the main the theory of the nutrition of phanerogamous plants; but while that is so, we must not regard as altogether absurd and out of the question the probability that the roots of phanerogamous plants may in some way be able to absorb organic matter. That the plants *can do* without the absorption of organic matter is not a proof that they *do do* without it. Our forefathers were well aware that in the accumulation of organic matter at the roots of plants, lay the success of husbandry. Since their time we have come to know that by the addition to the soil of what are called fertilisers, which are frequently mineral substances containing no organic matters, a great increase of crop can be obtained; but evidence is not wanting to show that during recent times the mere application of fertilisers has been in many cases overdone, to the detriment of the texture and condition, and even to the fertility of the soil. The result is that at the present time there is a renewed appreciation among the best farmers of the great value of organic matter as an ingredient of the soil on which its fertility depends.

If the observations of Professor Frank be correct, something will have been done to reconcile two views of plant nutrition that have hitherto been sharply at variance; but there are some difficulties to overcome before his theory of the symbiotic relation of the fungus, which he calls a *Mycorhiza*, and the forest trees can be accepted, in so far at least as the fungus is able to be regarded as supplying the roots of the tree with organic matter. An obvious objection to this view is that conifers and cupuliferous trees are provided with leaves whereby they can make their own organic matter; but, on the other hand, it may be said that there is no reason why trees should not obtain their organic matter from two sources. The one important observation which he adduces in support of that view is, that in the roots of trees nourished by the mycorhiza no nitrates are found. That is certainly a remarkable circumstance, which very distinctly differentiates them from most other plants in whose roots

nitrates are found as a constant constituent. Recent researches have shown that the nitrogenous matters in the soil, which are chiefly there in the form of albuminoid substances—the residues of former plants—are, in the process of decay, converted into ammonia salts, and these again into nitrates, through the agency of various bacteria inhabiting the soil; and that these organisms are so abundant and, in ordinary circumstances, so active that all nitrogenous matters which have become soluble in the soil are ultimately converted into nitrates, and that in that state they are absorbed by the roots of plants, and by means of proper chemical tests their presence can be detected.

Professor Frank observes that in the roots of trees or other plants affected by the mycorhiza he has not succeeded in finding nitrates, and this would seem to show that these roots are receiving their nitrogen from the mycorhiza in the condition of nitrogenous organic substances, viz. of elaborated organic matter such as is found in humus. It may be objected to the symbiotic theory that conifers and cupuliferæ can be grown in soil containing no organic matter. That is quite certain, and Professor Frank gives details of many experiments where trees of these orders were planted in sandy soils containing no mycorhiza both in pots and in the open, and in such cases no mycorhiza appeared upon the roots of the plants. They had the characters of normal roots, provided with hairs like the roots of other plants, and capable of taking up the soluble mineral matters contained in the soil. But he found that in such cases the plants, if they did not die down, maintained a sickly growth, which contrasted strongly with that of plants sown or planted under similar conditions, with the sole difference that they were supplied with humus in which the hyphæ of the mycorhiza were abundant.

The benefit that forest trees derive from the accumulation at their roots of the dead leaves and vegetable débris shed from above is known to all foresters, and also the injurious effects which follow the removal of this vegetable matter. It had hitherto been supposed that the benefit the roots derived from the covering of decaying vegetable stuff was simply that of protection against extremes of heat and

cold, and of drought and washing, the maintenance of an equable temperature and an equable dampness, both of which are favourable to the decay of vegetable matter, and its conversion into humus, which, besides vegetable matter, contains also the mineral substances most essential for the nourishment of plants. But if Frank's observations are thoroughly to be relied on, it would seem that humus has become invested with a new interest, as the dwelling-place, namely, of a fungus which assimilates what is most useful as plant food and conveys it to the roots of the trees.

So far from the mycorhiza being a parasite invading the trees, it would rather seem that the trees themselves were the parasites living on the fungus.

In order that a true case of symbiosis may be established, it would be necessary to show that the advantages enjoyed by the trees from the association with the fungus were reciprocated in some way. If the roots of the trees provided a nesting place for the fungus where it was able to breed or perform some function essential or advantageous to its development, then it might fairly be called a case of symbiosis. It seems, however, that only the vegetative part of this universally distributed fungus has as yet been found, and it is not known whether the process of reproduction takes place in the soil or in the roots of the trees, and, until that is known, the truly symbiotic character of it can be but imperfectly understood. It would seem, however, that its connection with the roots has this advantage, that it puts it in a position where it grows immensely more luxuriantly than it does when remaining unattached in the soil.

Since Frank's original paper was published, several investigators have made observations on the subject, with the result that the mycorhiza has been found affecting many other plants, notably Ericas and Orchids, and a number of plants whose connection with the soil, or I should rather say want of connection, has been a puzzle to botanists, such as *Paris quadrifolia* and the *Droseras*, which Schlicht, a pupil of Frank's, has been able to identify as mycorhiza affecting internally the roots of a large number of plants belonging to many natural orders.

To return to the subject of the assimilation of the free

nitrogen of the air by leguminous plants, you may remember that a very considerable body of evidence was adduced in support of the view that that order of plants possessed the power in virtue of their living in symbiosis with the Bacillus radicicola of Beyerinck, or, as Frank called it, the *Rhizobium leguminosarum*. That the Leguminosæ possessed a means of obtaining nitrogen which was denied to other orders, or at least possessed by them in a very subordinate degree, was known for ages; but it was not until quite recent years, culminating in Hellriegel's experiments, and recorded in 1886, that it was satisfactorily proved that the store of nitrogen which the leguminous plants were able to tap so freely was the uncombined nitrogen of the air, and that this power was associated with the growth of the nodules which that order of plants develop so abundantly upon their roots. Since the publication of Hellriegel's investigation, the formation and function of these nodules have been a subject of scientific research in all parts of the world, and these researches have been chiefly devised with the view of testing the accuracy of the symbiotic theory. To the results of such of these researches as have come under my notice, I wish now shortly to refer.

If the roots of the ordinary leguminous plants grown in the open field are examined, it will rarely happen that they are found entirely devoid of nodules. Nevertheless, in certain soils it is not uncommon to find good, healthy specimens that are quite free of nodules, showing that nodules are not absolutely essential to their development. Some genera are more prone to nodulation than others, and among these the lupine is pre-eminent. The lupine is also distinguished among leguminous plants as best adapted for green manuring, on account of the large amount of nitrogen which it is able to assimilate. But lupines also may be found growing vigorously without nodules.

That the nodules on the roots of leguminous plants are caused by the attack of a micro-organism in the soil is easily proved by growing the plants in a soil that has been sterilised by heat or otherwise, when it is found that no nodules then make their appearance. If to such a sterilised soil a few grains of unsterilised soil, or a few

drops of the washings of such a soil, be added, the roots of the plant are liable to develop nodules, and that liability becomes a certainty if the unsterilised soil is one in which similar plants well supplied with nodules have been growing. The nodules make their appearance at a very early stage in the plant's history usually, but it is not unusual to find quite newly-formed nodules on the roots of plants that are well advanced towards maturity. Nodulation may occur on the roots of almost any plants, and the nodules may be due to a variety of causes. The nodules here referred to are, however, of a special kind, and their anatomy has been carefully studied. They are due to the attack of a special organism. The generally accepted view is that it is a bacterium, and that it enters the plant by the hairs of the root. To discover the plan and mode of attack, and the propagation of the organism through the root tissue, is a matter of extreme difficulty, and it is not to be wondered at that there is considerable diversity of opinion regarding such matters. Frank, after much research, thinks he has discovered the spot on the root where a nodule will be formed, and around which will be clustered a mass of bacteria, allured to the spot by some inviting exudation emitted by the plant itself on purpose to attract them.

When the nodule has at length been formed, the changes brought about in the tissues of the root are easily seen. In a diagram of Frank's there is shown a microscopic preparation where the nodule from the root of a pea is permeated by what seems like the hypha of a fungus that has gained entrance by a hair and forced its way through the epidermis and cortical layer, and has caused the formation of modified cells in the meristem. These cells, under a high power, are found to be full of small Y-shaped bodies, to which the name of bacteroids has been given, and within the bacteroid are found very small highly refractive cocci, which are the bacteria which Frank calls *Rhizobium leguminosarum*.

In another diagram is shown a section of a nodule, taken from the root of yellow lupine, in which the infection has spread over a considerable part of the meristem, and it is important to note how the cells have multiplied by

division, and how the dividing cells are arranging themselves in rows perpendicular to the point of attack in front of, and circumscribing, the infected cells, and, as it were, setting up a barrier between them and the endodermis and the vascular bundles farther in, which give access to the circulating system of the plant. I seem to see in this arrangement an effort of the plant to oppose the advance of the intruder, and prevent, if possible, his gaining access to the vascular tissue within. The way in which one interprets such things is liable to take its form from the preconceived notion he has entertained regarding it. Frank starts with the notion that this is a case of symbiosis, and he imagines the plant as fishing in the soil for the bacterium, preparing a door for it, and entertaining it within its root as a welcome guest.

The manner in which the cells of the root increase and stand in between the infected cells and the vascular centre, pushing them out farther and farther until an excrescence in the form of a warty growth is made, calls to mind what takes place in animal bodies when invaded by parasites such as tubercle. The healthy tissue surrounding the intruder raises up a wall of defence, and endeavours to encapsule it, and so prevents it spreading. The bacteroids may, perhaps, not inaptly be compared with the phagocytes, which Metchnikof describes as mustering in force around the seat of an invasion, and not only surrounding, but incorporating the invading crowd of bacteria.

Either view of the matter is not inconsistent with the further development of the nodule, which increases often to a great size, and is usually connected with the root by a narrow neck. Also there is, if not always, at least usually, established a connection between the nodule and the vascular tissue, and the organisms within the nodule increase so as eventually almost to fill it. These organisms, be they bacteria or bacteroids, or both, are bodies rich in albumen, which is a highly nitrogenous compound.

The source of this albumen is a very vexed question. There are those who hold that the bacteria within the nodule get their nitrogen from the elementary nitrogen contained in the ground air. I believe that is the view which is generally entertained. It must, however, seem a

curious circumstance that the bacteria, if such is their function, should exercise it through the thick, corky layer of cells in which they are enclosed in the nodule, and that as they increase in number, and correspondingly in their demand for nitrogen, the wall surrounding them should be gradually becoming less permeable. This is at variance with what is found in other parts of the plant, such as in the chlorophyll cells surrounding the stomata, where the walls of the cells are made exceedingly thin, in proportion to the activity with which gases are required to diffuse through them. To discover whether nitrogen gas is entering the nodule through the walls is a very difficult matter. So far as it has been attempted by Kossowitch, who grew nodulate plants in a soil supplied with an artificial atmosphere composed of hydrogen and oxygen, but containing no nitrogen, it has gone to show that nodules grow independently of soil nitrogen.

One would naturally expect that if the nodules were for the purpose of absorbing nitrogen, they would be provided with delicate hairs, or in some way present an easily permeable membrane to the gas; but there is no such means provided, and there has been adduced no positive evidence in favour of the view that the nodule is a gas-absorbing structure. It has been suggested that the forked bacteroids within the nodule arrange themselves in a loose fashion, forming a network which presents a large surface to nitrogen gas, after the manner of the lungs of animals. This seems to me a fanciful notion, as it is highly improbable that a lung-like provision should be made for air which was not allowed access thereto.

We may now consider the other view held by Frank, and in which he is supported by Schlösing and Laurent, that the place where nitrogen assimilation takes place is the same as that wherein carbon assimilation takes place, viz. in the green leaves and other chlorophyll-containing parts of the plant. In support of that view there is the one very important piece of evidence, that the function of absorbing and assimilating atmospheric nitrogen and converting it into vegetable tissue has been shown by Berthellot, and André, and others, to be possessed by unicellular algæ which inhabit ordinary soils abundantly.

These unicellular plants containing chlorophyll are quite comparable with the single chlorophyll cells of compound plants, and are so like them in every way as to make it very difficult to deny to them the power of assimilating free nitrogen.

But while that goes so far as to make it a reasonable view, it does not explain why it is that the faculty of absorbing free nitrogen should be possessed by the chlorophyll cells of the Leguminosæ any more than by those of any other order of chlorophyll-bearing plants. Frank has endeavoured to throw some light on this by following up, as far as possible, the fate and progress of the bacteroids within the nodules and without. From a minute examination of the tissues of the root in the neighbourhood of the nodules, he finds that these organisms make their escape from the nodule in the root, and that they are to be found there especially in the riper stages of its life. It is his belief that long before the nodule softens and breaks down, and is in great measure absorbed by the plant, it is passing its bacteroids into the general circulation; and he has been able to detect these Y-shaped or forked organisms in the cells of the stem, the leaves, the seed itself, and even in the cotyledons of the young embryo of *Phaseolus vulgaris*. The identification of these minute organisms is attended with great difficulty, and there is considerable liability to error; but Frank is very strong upon the point that he is not mistaken in his search for these bodies, and if that is so, if his observation is to be trusted, and if it is really certain that the plant is permeated even very thinly with bacteroids, it makes it more easy to believe that under their stimulus the function of absorption of free nitrogen may be imparted to the chlorophyll cells, in virtue of their presence in some unknown way. It would, in that case, be more easy to compare the chlorophyll cell of the Leguminosæ with the unicellular algæ of the soil, for it is quite possible that these also owe their power of assimilating free nitrogen to a stimulus received from similar bacteria contained in the soil.

The finding of bacteroids in the cotyledons of *Phaseolus vulgaris* is also a matter of great interest, for if that is correct, and if the case is not an isolated one, it is evident

that the plant contains within it the means of producing nodules on its roots without having to be dependent on the friendly co-operation of bacteria resident in the soil. Moreover, if it were so, it should be possible to grow leguminous plants having nodules on their roots, even in a sterilised soil. That, however, is against all experience, for there is nothing on the subject regarding which experimenters are more agreed than that the plants grown in a sterilised soil should have no nodules on their roots.

Another important observation that militates against the view that the bacteria or bacteroids in the nodule are the direct assimilators of free nitrogen, is that when cultivations of the bacteria are made outside the plant in nutritive media containing organic matter of a suitable kind, they have not been found to absorb atmospheric nitrogen. They live upon the nitrogen contained in the nutritive solution, just as other bacteria do.

It will thus appear that the view that the free nitrogen assimilation takes place in the chlorophyll cells has by far the most support from experimental facts.

If that be so, then the store of albuminoid matter found in the nodules has not been brought to the plant as a free gift,—it has been supplied by the plant itself, and the question arises: Is this then a case of symbiosis? Is it not rather a case of pure parasitism, where the invading organism is preying upon the tissues of its host? If it could be shown that the host was impoverished thereby, and especially if it were injured, that would be the true name for it; but it is alleged that the host plant is greatly benefited, inasmuch as the stimulus derived from the bacteria enables it to assimilate far more nitrogen than it otherwise could, and that even that which goes to the nourishment of the nodule is only lent it for a time. As soon as the life cycle of the bacteria is over, the nodule falls into a state of decay, and the host reabsorbs the albuminoid matter that he has stored in the nodule as a surplus manufacture. True it is that, in the breaking down of the nodule, some of its contents escape into the soil, but that is regarded as an additional proof of the symbiotic relationship, for the bacteria which escape into the soil remain there, and, for ought we know, increase

and prepare themselves for bestowing a similar service upon the succeeding generation of leguminous plants.

It must be evident that in all this complicated symbiotic arrangement, an instance is presented to us of the danger of proceeding to investigate a chain of natural phenomena with a preconceived theory to which you hope that the facts will accommodate themselves. According to Frank, we are asked to believe that the plant baits its roots with something nice, to lure the bacteria to it; it opens the door to them, and leads them along through a lane into the body of the root, where they find a number of expectant cells organising themselves for their reception. These surround the bacteria as a kind of bodyguard, and conduct them to the vessels that enable them to enter the circulation of the plant. The plant constructs a special abode for them, and supplies them with nourishment, whereby they may increase and multiply; and only when it requires a large amount of albumen for the development and ripening of its seed, does it claim back the albumen it had lent. At the same time, with a prudent eye to the future, it allows a residue of the organisms to escape into the soil, sufficient in number to satisfy the requirements of all its progeny in the coming season. The symbiosis consists in this, that the plant supplies the bacterium with a breeding place and a store of food, and receives from the bacterium in return a stimulus which enables it to assimilate the free nitrogen of the air.

This is an interesting theory, but it will be thought by many that it claims for the Leguminosæ a little too much intelligence, cunning, and providential care.

There is a liability in working out a theory to select (unconsciously it may be) only those facts which fit in with it. Since the broaching of the symbiotic theory, other facts have come to light that can scarcely be said to fit in with it.

When Hellriegel first recorded his experiments he claimed for the nodules this advantage, that they enabled the young plants to assimilate atmospheric nitrogen at the precarious period of the youth when they had used up the nutriment stored in the cotyledons, and were thrown upon their own resources. This does not accord with the general experience of investigators, who find that the advantage to the plant is

observable only during the latter part of its growth, when its seed is forming.

As I have already observed, leguminous plants can grow to maturity quite well without the possession of nodules, so long as the nitrogenous matter they require for their growth can be obtained easily from the soil. Plants grown in a sterilised soil and supplied with nitrates, as well as the other plant food required, grow to perfection, and in a natural unsterilised soil, rich in plant food, where the assistance of nodules to enable the plants to obtain nitrogen from the air is unnecessary, they may have their roots abundantly studded with nodules. Frank describes an experiment with *Phaseolus vulgaris* grown in a poor sandy soil containing only about ·01 per cent. of nitrogen, where the plants grown in sterilised pots and unsterilised pots, with inoculated and uninoculated, grew in very much the same way, and that very poorly; and when grown in a soil rich with nitrogenous organic matter the beans grew exceedingly well, but quite indifferently as to whether it had been previously sterilised or not, or whether it had been inoculated or not. He came to the conclusion that *Phaseolus* behaved toward the *Rhizobium* as if it were a non-leguminous plant, but that, you may remember, was the plant within whose cotyledons he succeeded in tracing the presence of bacteroids.

A very instructive series of experiments was carried out by Dr. Stocklasa in 1894, with the view of ascertaining whether there was any necessary connection between nodule formation and the formation of nitrogenous tissue in leguminous plants, and he chose for his subject of experiment *Lupinus angustifolius*, which he grew upon a light sandy loam, poor in nitrogen, in the open field.

He selected, while in bloom, ten well-grown plants with nodules on their roots, and ten others of similar growth without nodules. The two sets of plants were as equal in every way as could be wished, having twenty-three and twenty-two leaves per plant respectively. These he analysed, and found that there was practically no difference in the amount of nitrogen they contained. The only difference noticed was that the nitrogen was somewhat unequally distributed. The plants with nodules had rather more

nitrogen in their roots, those without nodules had rather more in their leaves. The nodules themselves contained as much as 4·5 per cent. of nitrogen.

He also grew lupines in pots containing washed sand, to which he added fertilising materials such as plants require, in the form of a solution made perfectly sterile, and with which the plants were watered, but in this nutritive solution there was no nitrogenous matter. Moreover, the pots were covered with wadding to protect them from infection of any kind by means of air-borne spores. Ten lupine plants thus grown assimilated from the air ·191 grams nitrogen. These roots had no nodules. Ten lupine plants treated in the same way and grown in the same kind of soil, to which a few grams of unsterilised lupine soil were added so as to inoculate the earth, assimilated 1·575 grams of air nitrogen, viz. about eight times as much as the others, and their roots were well studded with nodules. So much for the lupines grown in sterilised soil with and without inoculation, and, consequently, with and without nodules.

He made a parallel experiment with lupines grown in an unsterilised poor soil, consisting almost entirely of sand dug out from several feet below the surface of the ground, and almost destitute of organisms. They were treated with the non-nitrogenous solution as the others, but the surface of the soil in the pots was left exposed to the air.

He inoculated one-half of the pots with a few grams of lupine soil, and left the other half uninoculated.

In the inoculated half the roots of the plant were well grown with nodules. On the uninoculated half, only a few imperfectly developed nodules appeared in several of the pots.

He selected ten plants from each division, viz. ten plants with nodules, and ten plants without, but otherwise well grown, and analysed them, with the result that there was almost no difference in the amount of nitrogen the two lots had assimilated from the air. As it happened, the uninoculated lot that had no nodules assimilated rather more than the other. The quantities were—

Without nodules .	2·126	grams nitrogen.
With nodules . .	2·09	„ „

These quantities are more than ten times as great as that assimilated by the plants grown in the sterilised and uninoculated soil. The result of this experiment is to show that inoculation is of use in a sterilised soil protected from air-borne organisms. In that case the inoculation and the nodulation resulting therefrom increased the nitrogen assimilation eightfold, but, in the case of an unsterilised and unprotected soil, inoculation and consequent nodulation made no difference whatever.

The explanation of this unexpected result is that the soil of the unsterilised pots was thickly grown with algæ, and well supplied with bacteria; and it is to the activity and nitrogen-assimilating power of these that the plants owed their increased assimilation. In other words, the plants received their nitrogen from the soil, and that nitrogen was brought into the soil from the air by the algæ and bacteria which flourished there. If this be the true explanation, it does away entirely with the symbiotic relation supposed to exist between the Leguminosæ and the bacteria contained within the nodules. We are still left with the fact that nodulation is due to the interference of bacteria, and that the nodules are highly nitrogenous bodies whose nitrogen, however, is entirely derived from the plant, and utilised eventually by it for the growth of its own seed, should the plant ever arrive at the seeding stage. If that is all, the attack of the bacteria on the roots, and its subsequent lodgment there in the form of a nodule, must be regarded as pure parasitism, and that the plant eventually absorbs the organic matter of the parasite in its mature stage is due to its having sufficient vigour to confine the parasite within a nodule, and so to limit the sphere of its mischief.

Whether, in the event of the plant's not possessing that vigour, the bacteria would get the upper hand of it and kill it down, is a probability that has been suggested, but of which I have no proof.

It is evident, however, that such a condition of matters may occur, and it may, upon further investigation, shed some light on the mysterious disease of clover sickness, and of some other apparently parasitic disease to which some leguminous crops are liable.

It may be objected to the results of Stocklasa's experiment that they do not explain why it is that leguminous plants should be the only ones able to derive benefit from the nitrogen brought to the soil by the algæ and bacteria referred to. That question Stocklasa answers in a somewhat unexpected manner. He gives the result of five years experimenting with buckwheat (*Polygonum fagoyprum*), a plant far removed from the Leguminosæ, and shows that it also has the power of assimilating atmospheric nitrogen, especially when grown in soils that are fairly well supplied with nitrogenous manure.

Into the details of that experiment time will not permit one to enter, but the results are shortly as follows :—

100 plants grown in a *sterilised* soil assimilated of atmospheric nitrogen	·138 grams.
100 plants in an *unsterilised* soil . . . . (That is to say ten times as much.)	1·378 ,,
100 plants grown in a *sterilised* soil to which ammonium nitrate was added as a manure	3·385 ,,
100 plants in an *unsterilised* soil similarly manured	6·09 ,,

This experiment, besides putting on record the fact that plants other than leguminous ones can utilise atmospheric nitrogen, shows how greatly dependent for that faculty they are upon the lowly organisms that inhabit the soil in which their roots are ramifying.

Time will permit me to do no more than refer in a few words to an experiment, which, through the kindness of Professor Balfour, and with the valuable assistance of Mr. Harrow, I was able to carry out at the Botanic Garden last summer. The experiment was only a provisional and tentative one, as a prelude to one which I hope to try next summer.

A soil made of a very poor subsoil, about three feet below the surface, which had been laid bare during the building improvements going on in the Garden, was chosen on account of its poverty in nitrogen, and it was mixed with sand in equal amount. To this was added a supply of fertilisers, viz. phosphate and potash salts, but no nitrogen. This was filled into three sets of pots, measuring eight inches across, and containing about five pounds of soil each. One-third of the pots was left without further manure, and the other

two-thirds were supplied with nitrogenous manure, one-half with sulphate of ammonia, and the other with flesh meal, and these in varying quantities. Half of these were sterilised by exposure for some time to steam at the boiling-point of water. Moreover, a duplicate of the whole series was made, to which was added nitragin, a supply of which I got from the manufactory in Germany, of the kind specially prepared for application to the bean crop, in the manner described in Mr. MacDougall's paper, read before the Society last session. This was dissolved in water in the manner recommended by the vendors, and applied to the crop after the leaves appeared above the soil.

The sterilised pots were protected with wadding for some time, but its use was discontinued when the seed began to germinate. They were watered with sterilised water. Five beans were planted in each pot, and all were sterilised by dipping in a solution of corrosive sublimate of 1 to 4000 before planting, both in the sterilised and unsterilised section. The pots were accommodated in a cold frame when the experiment began in July, and kept there till October, when it ended.

The experiment was only a preliminary one, carried on chiefly to enable one to gain some experience, so that a quantitative record of the result was not made.

It was found that the plants that throve best were those that had no nitrogenous manure given them. There was a large number of blanks, and in very few pots did all the five beans come up. The division that got no nitrogenous manure was a fairly even one. The plants that did grow were healthy, and most of them were in full flower when the experiment ended. There did not seem to be much difference between the sterilised and unsterilised sets, nor was there any perceptible difference between the pots that were inoculated with nitragin and those that were not. A fairly representative collection was made of the plants in each set. They were carefully turned out of the pots and put into water, so that the earth might fall away from the roots without injury of any kind. I preserved a number of the roots in formation, and removed the stalks. A number of them are shown on the table before you. Four are from sterilised pots, and four from unsterilised ones. Upon the

whole, I am of opinion that the plants grown in sterilised earth rooted the best. The steaming of the soil may have had the effect of making nutritive substances more easily assimilable, but the difference was not great.

As regards the application of nitragin, from which so much was expected, it does not seem to have had any effect whatever either upon the growth of the plant, the development of the root, or the occurrence on these of nodules. Some of the plants that were inoculated with nitragin had nodules upon their roots, and some had none, but the nodules on the nitragined roots were no more numerous nor were they any better developed than those on the set that got no nitragin. This is a disappointing result, but it is similar to that recorded by Professor Somerville in the paper he laid before the Society last session. In searching for the cause of the failure of this much-advertised material, there are various circumstances that may be considered.

The bean is not quite so sensitive to inoculation as some other members of the Leguminosæ, and Frank describes an experiment with *Phaseolus vulgaris* in a somewhat similar soil, where nitragin had no effect in increasing the crop whatever, and where, indeed, the plants that were unsterilised and uninoculated throve best and gained most nitrogen. Frank thought the failure was due to the soil being too poor in organic matter, but if that were so, it was a fatal objection to the use of nitragin, whose chief use and whose greatest virtue was considered to be its capability of enabling leguminous plants to grow on soils poorly supplied with organic matter, and at the bottom of the scale as regards richness in nitrogen. The whole system of growing leguminous crops for manurial purposes is to enrich the soil with organic matter, and especially with nitrogen from the air. Soils rich in organic matter are just those that do not require to be treated in that way.

Again, perhaps the benefit of nitragin was not felt sufficiently because the plants were cut down before maturity, but if that is so, it again tends to nullify the benefits derived from leguminous plants that are grown for green manuring and for increasing the store of nitrogen in the soil, for green manure crops are ploughed up long before they ripen.

Again, it may be that the whole experiment was too late in the season, or it may be that the soil was otherwise unsuitable, or it may be that the nitragin had lost its vitality, or it may be that it does not possess some or any of the virtues ascribed to it. I hope, during the coming season, to be able to say which of the many hypothesis that may be started are of any importance, for I hope to be able to anticipate every possible objection that a believer in the value of nitragin might be expected to raise.

Measurement of the Girth of Coniferous Trees at Braemar in 1894. By R. Turnbull, B.Sc., and Percival C. Waite. (With Plate.)

(Read 9th December 1897.)

During April 1894 we spent a fortnight at Braemar, and had many opportunities of observing the destruction caused by the great November gale of 1893.

Every wood and forest in the neighbourhood had suffered, and the foresters had been busy during the winter sawing the blown trees into logs. We determined to measure the radii and annual increment of diameter of specimens of Scots pine, Norway spruce, and common larch, so as to be able to calculate the annual increment of girth.

Those trees had all, with one exception, grown on the slopes of steep hills, and it was found that the side of the tree which was most obscured by the hill or other trees presented the smallest radius, while the longest radius was turned towards the greatest light.

Thus we found the greatest radii on the N., E. and S. sides respectively, in trees with an open aspect in those directions. In none of our specimens did we find the greatest radius to the W., but this may be merely an accidental occurrence, and one to which at present we can attach no importance.

It is a law in plant-growth that leaves and the young aërial parts of plants turn towards the light. This pheno-

menon must not be mistaken for the bending of trees on exposed situations by the prevailing winds.

On the edges of dense woods and forests, trees have most branches on the side turned to the light; fewest on the side next the mass of the forest. These conditions hold good for the specimens under consideration, therefore we find the greatest development of branches on the same side as the greatest radial increment.

Now, since the elaborated sap or digested food of the tree is made in the green leaves, it evidently descends the tree mostly by the bast of the side on which it is manufactured, and thus brings about the radial increment of wood on that side.

The breadth of the annual rings showed that most of the trees had reached the limit of most active growth in girth at the ages of 30 to 50 years, but in some cases the growth was continued long beyond this age, with only a very gradual decrease of vigour.

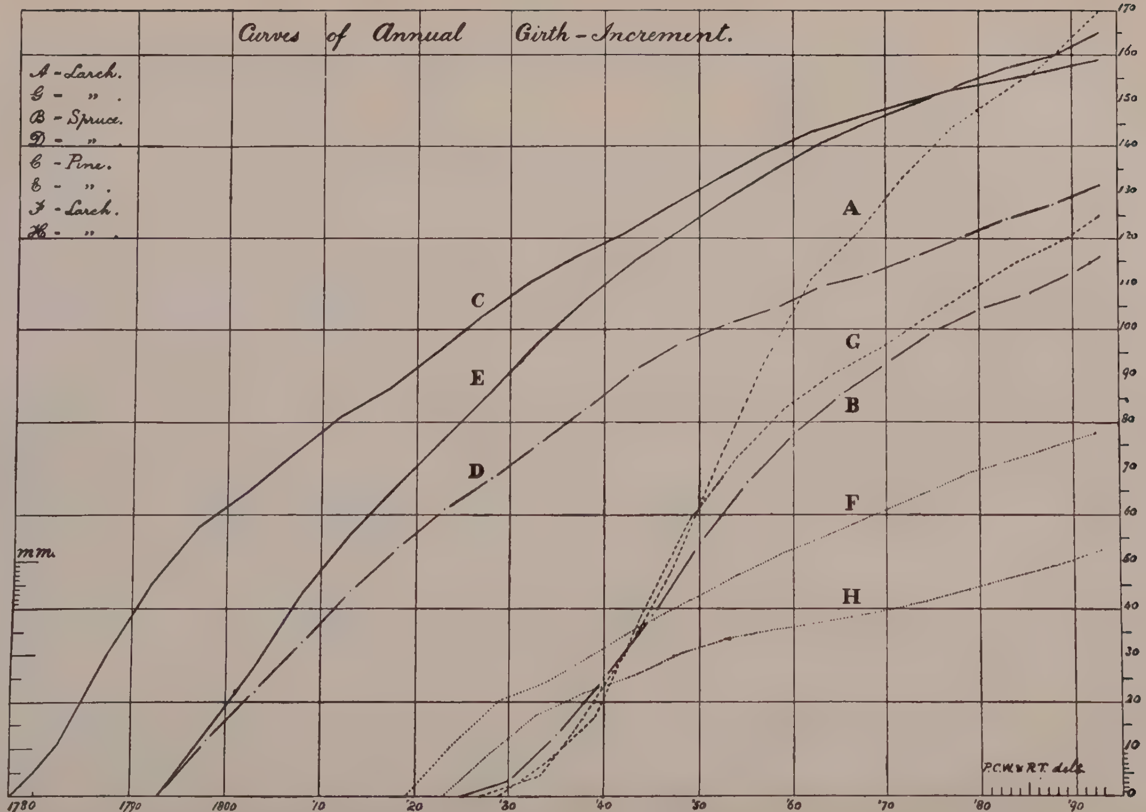
Among the broad annual rings in the older parts of the tree much narrower rings were occasionally found; in the same way, broad rings occasionally among the narrower rings of the younger wood. It is almost impossible to determine definitely the causes which bring about such variations from year to year. In the absence of a detailed history of each tree, the question of thinnings must be left out of account, although it is well known that a judicious thinning affects most beneficially those trees that are thus more exposed to the light and heat of the sun.

The trees in question, to all appearance, had grown with plenty of space all round, and had not been forced into the pole-stage, according to the principles of modern sylviculture.

Again, the frequency of the variations, above referred to, shows that periodic thinnings could not be the sole cause.

Soil and situation were constant factors throughout, except that, as growth in height proceeded, an increasing density of leafy canopy would be the result, but this would not account for the variation.

Frequent storms might, by removing certain trees, expose the survivors to greater light, but storms of this



Curves of Annual Girth-Increment.
A - Larch.
G - " .
B - Spruce.
D - " .
C - Pine.
E - " .
F - Larch.
H - " .
mm.
A
B
C
D
E
F
G
H
1780
1790
1800
'10
'20
'30
'40
'50
'60
'70
'80
'90
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
P.C.W. & R.T. delt.

nature become historic, and do not occur often enough to account for the variation.

Other meteorological conditions, however, must be taken into account, since they form some of the factors which determine the growth of all plants; these are temperature, moisture, and sunshine. The relationship of these factors to the annual increment of girth will form the subject of a second paper.

The following were our methods of examining each tree:—After choosing an evenly-sawn section close to the ground, we found its orientation by means of a pocket compass, then cut two smooth tracks on the surface with a wood chisel so as to get N. and S., and E. and W. diameters, each passing through the pith.

The total lengths of each diameter, and each radius, were measured by us in turn, while the other noted the measurements on paper; then the breadth of each annual ring was taken with a steel millimetre measure, and these measurements were checked at every tenth year.

It must be understood that the measurements were made of the wood only, and did not extend beyond the cambium.

When the annual rings of the first few or the last years of a tree were too close for accurate individual measurement, a collective number was measured.

Specimen *A* was thus measured collectively for the first 6 years; *B* for the first 5; *D* for the last 30; *E*, *F*, and *G* had every annual ring measured along each of the four radii; *H* had a few collective measurements taken between the ages of 25 and 50 years.

The sections were immediately above the ground-level, except—*D*, 12 feet above ground; *F*, 32 feet above ground; and *H*, 34 feet above ground.

It would have been better to have got sections 4 or 5 feet above ground, so as to be away from the buttressed part of the trunks near the roots; but we had no choice, since we had to examine the sections as we found them.

In calculating the girth for any one year, the increments of the four radii of that year are added to the sum of the radii of all the preceding years; the total is divided by 2

to get the average diameter, and the quotient multiplied by $3\frac{1}{7}$ to get the girth for the year.

The continued increase in the four radii, the average diameter and the girth for each year, are represented by curves, where the co-ordinates are years, for the age of the tree, *i.e.* horizontal co-ordinate or abscissa; and millimetres for the girth, *i.e.* vertical co-ordinate or ordinate.

The actual scale on the diagrams shown is 5 years to one inch horizontally, and 100 mm. to one inch vertically.

The curves for the four radii, average diameter, and girth of each tree are represented for periods of 5 years, and where collective measurements were made an average for each quinquennial period has been struck.

On separate diagrams a life-size section of each tree, calculated from the four radii, and marked with rings every 10 years and at the cambium, has been drawn; and on these sheets, also, has been drawn a section of the ground showing its gradient and the position of the tree.

The following are the details of the specimens examined:—

A. Common larch (*Larix europæa*, DC.) was situated at the N. side of the Inverey road, and close to its edge, about two miles to the west of Braemar, near the point where the road runs to the S.S.W., so that the S. and W. sides would receive most light. Immediately above were the lower slopes of Morrone, which rises to a height of 2819 feet, and the tree itself stood about 1200 feet above sea-level. The ground sloped gently at first, and then precipitously to the Dee on the N., the river being within a stonethrow of the tree.

Trees grew all round, and the only open ground was towards the road, while from the slope of the ground there was more light on the N. than on the E. side.

The S. radius	measured	324	mm.
„ W. „	„	296	„
„ N. „	„	239	„
„ E. „	„	220	„

As shown by the curve for the increment of girth, the growth for the first 6 years was slow, then came rapid growth up to 15 years, and a still more rapid growth up to

35 years, after which the gradient becomes less, and after 50 years of age there is a considerable falling off, with a slight increase, however, during the last 6 years. The last increase in the gradient should be specially noted, as it occurs in all the trees examined, but it will be discussed in the second paper.

The girth increase was most vigorous from 20 to 35 years of age, but good, sound growth was made up to 50 years of age. The tree was 66 years old, and the total girth of wood was 1695 mm., *i.e.* 5 feet $7\frac{4}{5}$ inches.

B. Norway spruce (*Picea excelsa*, Link.) grew about a furlong W. of *A*, on the same side of the road, but much farther down the hill. It had trees all round, and the only open aspect was to the N., where the ground sloped very rapidly down to the Dee.

The	N.	radius measured	201·5	mm.
„	S.	„ „	186·5	„
„	W.	„ „	178·5	„
„	E.	„ „	175·0	„

The girth curve shows at once that the conditions had been less favourable for the spruce than the larch.

The first 5 years' growth was slow, then came a more rapid and almost uniform growth up to 30 years of age, after which the gradient becomes smaller and smaller until 60 years of age, from which time until the tree was levelled, at the age of 68, there was a slight rise. The total girth of wood was 1165 mm., *i.e.* 3 feet $10\frac{2}{5}$ inches.

C. Scots pine (*Pinus sylvestris*, L.) grew on the N.E. slope of Craig Choinnich, a very steep wooded hill which rises about a mile to the east of Braemar into a sharp peak, 1764 feet above sea-level.

Below the place where this tree grew, the public road to Ballater, distant only a few yards, runs in an E.S.E. direction. Trees grow down to the road, while close to the latter, on the N. side, is the Dee, and beyond the river lie open meadows. The open aspect was thus on the N.E. side of the tree, and it is noteworthy that the N.E. radius was 319 mm. long, but this radius is not taken into account in calculating the girth, as uniformity was desired in all the calculations.

The E.	radius	measured	291 mm.
„ N.	„	„	252 „
„ W.	„	„	252 „
„ S.	„	„	215·5 „

The S. side of the tree was obscured by the hill and the trees above.

The curve of girth shows slow growth up to 5 years, rapid growth up to 20, and less rapid up to 85, after which the gradient becomes less steep.

The tree reached the age of 116 years, and its girth measured 1588 mm., *i.e.* 5 feet 3½ inches at the cambium.

D. Norway spruce (*Picea excelsa*, Link.) grew quite close to *C*, but differed from all the preceding in being cut 12 feet above ground. Like *C*, its E. radius is greater than any of the other three.

The E.	radius	measured	298·5 mm.
„ N.	„	„	229·0 „
„ S.	„	„	159·0 „
„ W.	„	„	158·5 „

The girth curve shows a good and fairly uniform growth up to 50 years of age, but it must be remembered in this case that, to allow for the 12 feet above the ground, we must add 15 or more years to the age of the section to obtain the actual age of the tree.

In all probability it was planted at the same time as its neighbour *C*, the Scots pine.

According to our measurement the age of the section was exactly 100 years, and its girth of wood was 1314 mm., or 4 feet 4½ inches.

E. Scots pine (*Pinus sylvestris*, L.) grew on the same slope of Craig Choinnich as *C* and *D*, but some distance to the W. of the latter, near the edge of the wood, and almost opposite Braemar Castle. This change of position removed the tree from the close shadow of the hill, and opened up the S.W. and W. aspects.

Like *D*, the tree was cut a few feet above the roots, but, unfortunately, the exact height was not recorded.

The S.	radius	measured	313·5 mm.
„ W.	„	„	256·1 „
„ E.	„	„	248·0 „
„ N.	„	„	236·0 „

The girth curve of the tree is the most uniform of the series, but owing to the height of the section above the ground, the first few years' growth is wanting.

The crown of the girth curve shows the tree to have reached its best between the fortieth and fiftieth years, but even up till the last it retained much of the vigour of its youth.

The last five years show a slight increase of gradient. The tree at the section had reached 100 years of age, and measured 1654 mm., or 4 feet $8\frac{1}{8}$ inches in girth.

F. Common larch (*Larix europæa*, DC.) grew on the S.E. slope of Carn-na-Drochaide, about half a mile S.W. of Inverchandlick Cottage, on the N. bank of the Dee. The slope was gentle, the tree grew several yards back from the road which opens the aspect to the N. and E., but it is difficult to obtain the exact surroundings of the tree at the level of the section, which was 32 feet above ground.

The tree grew about 1060 feet above sea-level.

The N.	radius	measured	135·5	mm.
„ E.	„	„	134·0	„
„ S.	„	„	115·5	„
„ W.	„	„	111·0	„

Since the section was taken 32 feet above ground, one must add about forty or fifty years to the ascertained age to get the age of the tree.

The age of the tree at the section was 74 years, and the girth 779 mm., *i.e.* 2 feet $7\frac{1}{6}$ inches.

G. Common larch (*Larix europæa*, DC.) grew on level ground about half a mile N. of Braemar, among a clump of trees to the N.W. of the cemetery, and near the old toll-bar which stands at the junction of the main road with that which leads to the ferry over the Dee.

An old gravel pit lay immediately to the N. and E. of this tree, while the S. and W. sides were shaded by other trees.

The whole trunk was lying on the ground, and we found it to be 54 feet high, while the section was measured at the ground level.

The N.	radius	measured	257	mm.
„ E.	„	„	200	„
„ W.	„	„	173	„
„ S.	„	„	165	„

The growth was fair up to 10 years of age, much quicker up to 20, somewhat slower up to 30, and then considerably slower up to 64, the age of the tree. The girth at the stool measured 1249 mm., or 4 feet 2 inches.

H. Common larch (*Larix europæa*, DC.) grew beside *F*, on the N. side of the Dee, and the section was taken 34 feet above the ground. As in the case of *F*, it is difficult to learn the conditions of light and shade of this tree.

The E. radius	measured	91·5	mm.
„ S. „	„	86·0	„
„ W. „	„	79·0	„
„ N. „	„	79·0	„

The curve is of the same nature as that in *F*, but the growth had been slower. The tree at the section was 70 years old, and measured only 527 mm., or 1 foot 9 inches in girth.

The diagrams referred to in the text were used to illustrate the reading of the paper; the only one reproduced here is that showing the curves of annual girth-increment.

THE DIAMETER-INCREMENT OF THE WOOD OF CONIFEROUS TREES AT BRAEMAR IN RELATION TO CLIMATIC CONDITIONS. By R. TURNBULL, B.Sc. (With Plate.)

(Read 13th January 1898.)

The first part of this paper, read at the December meeting of the Society, dealt with the measurements of the radii, average diameters, and girths of the wood of coniferous trees which were blown down near Braemar by the November gale of 1893.

Curves of the continued increase of diameter and girth were drawn for each tree, so as to show the increase in relation to age, and since the paper was read, curves for the increase of area have been added.

There were eight sections examined, including larch, Scots pine, and Norway spruce, and in every case the

largest radius was found to be on the side exposed to the greatest light.

The present paper is an attempt to find a relationship between the annual diameter-increment and the climatic or meteorological conditions. A better plan would have been to compare the annual area-increment with those conditions, but the additional labour of calculating the areas for each year would have extended the work over another month; by this latter method, however, the average height of the curves would have been maintained; whereas, by using the diameters only, the average heights of their curves naturally decrease with time, because, as the girth of the tree expands, the average increment of the diameter decreases.

There is very little lost in the method adopted, since girth and area are continuous functions of the diameter. The rise and fall seen in the diameter curves would be seen at the same places in the girth and area curves, only they would be more pronounced in the last two.

Of the specimens mentioned in the first paper, only five could be used for the purpose of drawing out continuous curves of the annual diameter-increment, because in these cases the measurement of each annual ring had been taken, while in the three omitted from the present paper measurements had often to be taken of 5 or more years collectively, owing to the smallness of the rings.

Meteorological observations have been made at Braemar since 1856—the greater part of the time by Mr. James Aitken, the present observer—at the Observatory founded by H.R.H. the late Prince Consort in 1855; and the observations from 1856 to 1893 were reduced by Mr. R. C. Mossman, F.R.S.E., and recorded in the "Journal" of the Scot. Met. Society (Vol. x., Third Series, No. x., 1894).

From Mr. Mossman's tables I have calculated means for periods of three and six months respectively, while the tables supplied the yearly means; and curves have been drawn for temperature and rainfall, showing the three-monthly periods, beginning with January of each year.

By uniting the second and third periods and taking the averages, the curves for the growing season—April to September inclusive—have been obtained. My object in

doing this is to get the direct influence of these conditions while the trees are actually growing.

The mean temperature and rainfall for the year do not represent the means for the summer months; at the same time the means for the winter and spring months, and also for the year, have been before me in studying the curves of increment.

The relative humidity of the air during the six growing months has been represented by another curve.

I am indebted to Dr. Alexander Buchan, Secretary, Scot. Met. Society, for kindly placing at my disposal his MS. tables of sunshine for the whole of Scotland, and from these tables curves have been drawn; these curves, however, are only approximately true for Braemar, but they are a great help to the present investigation, as light is an important factor in the growth of plants.

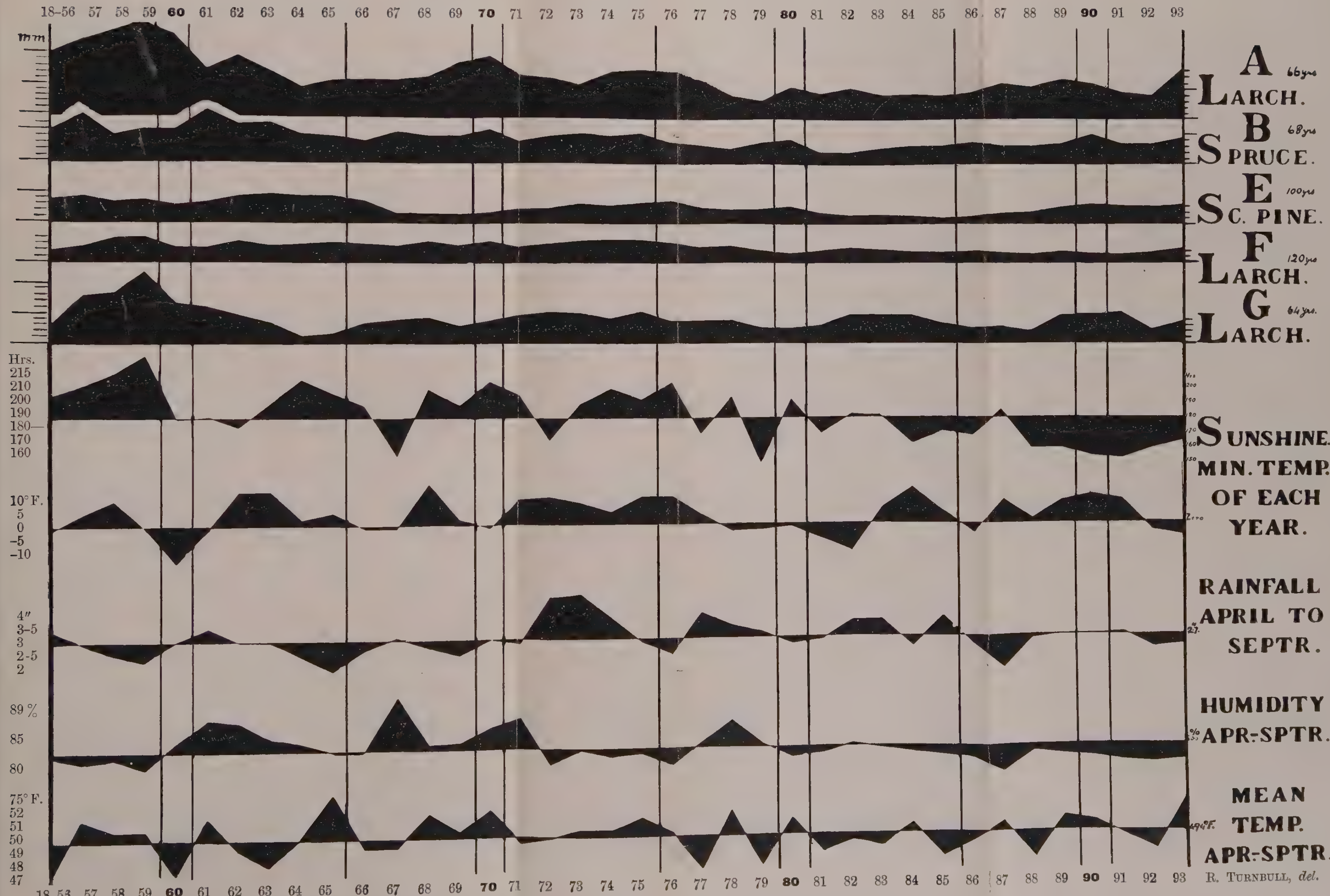
Since the meteorological observations at Braemar began, in 1856, I had to make that year the starting-point for my curves; the period under consideration is, therefore, 38 years.

The following are the specimens now under consideration:—Specimen *A*, common larch, 66 years old at section near the ground; on N. slope of hill; S.W. exposure. Specimen *B*, Norway spruce, 68 years old at section near the ground; on N. slope of hill; N. exposure. These two trees grew about 2 miles west of Braemar, and about 100 feet above the river Dee. Specimen *E*, Scots pine, 100 years old; on N. slope of hill, one mile E. of Braemar, and 20 feet above the Dee; S.W. exposure. Specimen *F*, common larch, 74 years old, but section at 32 feet above ground, so that tree must have been considerably over 100 years old; 1 mile N. of Braemar, on S.E. slope of hill N. of the Dee; exposure uncertain. Specimen *G*, common larch, 64 years old at section near the ground; on level alluvial soil, with gravel subsoil, ½ mile N. of Braemar; exposure N.E.

From these notes and the first part of the paper it will be seen that conditions and aspects of the trees varied considerably, and these may account for some of the minor differences found in the curves.

A more accurate method of investigation would be to

CURVES OF ANNUAL DIAMETER—INCREMENT.



secure a large number of trees from the same neighbourhood, and of approximately the same age, so as to compare their curves of increment.

While considering the external influences of a plant, one must not overlook the internal conditions. Perennial plants store up the surplus food of one year to be used during the following year, but the balance carried over from one year to another depends largely on the conditions of growth; consequently the growth of any one year is not wholly dependent on the meteorological conditions of that year, but also on the reserved food materials, which, in turn, are dependent on the meteorological conditions of the preceding year.

Again, insect attacks and severe frosts may so injure the buds and leaves of trees during the growing season as to make their effects felt over a period of years.

These are some of the difficulties to be met with in trying to account for the rise and fall of the increment curve.

Sylvicultural methods have never been adopted where those trees grew. I am assured of this by Mr. John Michie, head forester, Balmoral; the trees were planted and left to nature, consequently thinnings need not be considered. Gales of wind may have levelled trees around the specimens now under consideration; but, although Mr. Aitken in his reports notes the occurrence of gales, he mentions only that of November 1893 as having been destructive to trees.

If the curve of larch *A* be examined, it will be seen to contain six well-marked maxima in 1859, '70, '75, '82, '89, and '93 respectively, as well as a few other maxima of less importance; and three deep minima in 1864, '79, and '92 respectively, and several other depressions. To understand these points it must be remembered that larch thrives best in a dry, sunny atmosphere.

The maxima of 1859, '70, '75, and '82 occurred when the amount of sunshine for the growing season was above the mean. The minima of 1879 and 1892 occurred when the sunshine was very much below the mean. The minimum of 1864 occurred during one of the maximum sunshine periods, and, as this occurrence seems to contradict

the coincidence of sunshine and increment, it will require to be explained in terms of temperature and moisture. The six maxima agree still more closely with the periods of maximum temperature, as each coincides with the temperature at or above the mean. The three minima also occurred when the temperature was considerably below the mean.

The 1864 minimum followed the very cold summer of 1863, and in 1864 the temperature was only very slightly above the mean.

Let us now follow the curve in detail from 1856 onwards. The rise from 1856 to 1859 took place during continuous warm, dry, sunny, growing seasons.

The fall of 1860 came with a very cold, sunless, and moist summer. The season of 1861 was warmer, but the other conditions did not improve, and rainfall and humidity were much above the mean. The cold of 1860 would allow of very little reserve food, while the increased moisture of 1861 would hinder growth, and these two conditions are sufficient to account for the continued fall in 1861.

It is difficult to understand the rise of 1862, but the increment for that year is small when compared with the five years preceding 1861, and it may partly be accounted for by the lessened rainfall of 1862, although the temperature was below the mean.

The very cold season of 1863, added to the relatively cold season of 1862, brought about a further fall, which was continued until 1864, when the first minimum was reached.

The temperature of April, May, and June 1864 fell below the freezing-point, and this may have helped to check the growth.

From 1864 to 1870 there was a steady rise, due largely to the increased sunshine, higher temperature, and lessened rainfall of those years, excepting the cloudy, colder, and moister year of 1867, which caused a slight dip in the curve.

The temperatures of 1867 and 1868 were not sufficiently far below the mean to do more than lower the curve slightly in its upward rise, but in 1869 and 1870, with warmer, sunnier, and drier seasons, the rise was rapid.

The second great maximum is thus found in 1870, when all the most favourable conditions of growth for larch occurred. The curve between 1870 and 1875 first falls and then rises with the sunshine and temperature, while the lowest point of this period coincides with the very heavy summer rainfall of 1873, almost equalled by the summer rainfall of 1872. The rise of 1875 marks the third of the great maxima, when the conditions were similar to those of the first maximum in 1859.

A decrease of increment took place from 1875 to 1879, during a cold, wet, and cloudy period. There was a rapid rise in 1880, due to a warm, dry, sunny season; a fall in 1881 coinciding with a cold, cloudy summer; and another rise—the fourth maximum—in 1882, when sunshine and temperature were greater than in 1881, and, although the rainfall was greater, the relative humidity was very little above the mean. From 1882 to 1889 there was a fall, and then a rise with the sunshine and temperature. A decided rise occurred in 1887, when sunshine and temperature were above the mean, and when rainfall and humidity were low. The fifth great maximum of 1889 coincided with high temperature, an average rainfall, low humidity, but low sunshine and somewhat cloudy skies.

The fall from 1889 to 1892 corresponded with decreasing sunshine and temperature; 1892 was the third great minimum, and was probably due to low temperature and sunshine.

The rapid rise of 1893 appeared with the highest mean summer temperature after 1865, while the sunshine, though below the mean, was higher than during the preceding five years.

With regard to the curve for sunshine, the first half of the period of 38 years seems to have been sunnier than the second half; but one must eliminate the personal equation, because during the earlier years the estimation of sunshine was very largely guess-work.

The curve would probably be nearer the truth were one to depress the first half, and raise the second half. This would alter the mean, but the rise and fall of successive years would remain. In this way the year 1891 would be below, and 1893 perhaps above the mean.

The other curves may be taken as accurate, because they all are derived from the records of standard-tested instruments. One may err in trying to account for the rise and fall of the increment in separate years, but there is a marked periodicity of years which synchronises so closely with the meteorological conditions as to place beyond dispute the question of its external cause.

During the 38 years there were never more than four out of the six growing months without frost in any one year. In 1881, '85, and '92, there was only one month each year without frost, but it is almost impossible to trace the effect of those summer frosts in the growth of the trees; it is interesting to note, however, that each of these three years corresponds with a minimum or slight depression in all the five trees under observation.

Finally, it seems clear that, temperature being uniform, increase of rainfall and decrease of sunshine depress the increment; but it is also evident that, rainfall and sunshine being uniform, the increment decreases when the mean temperature of the growing six months falls to or near 48° F., while the increment increases when the temperature rises to or near 50° F.

F is the second larch, but as its age was probably nearly twice that of *A*, its curve is necessarily a very low one.

It shows maxima at 1859, '62, '70, '75, '82, '89, and '93 agreeing with those of *A*.

It has minima at 1861, '85, and '88 agreeing with those of *A*, but the minimum of 1864 is wanting, and, instead, it has a minimum at 1863, and also another in 1880, *i.e.* a year after the 1879 minimum of *A*. The section was above the level of the lowest and largest branches, and at that level the growth seems to have been more directly influenced by the rise and fall of temperature each year, although there are also traces of one year affecting the growth of the next, as in 1860, '61, '79, '80, '84, and '86.

The curve of larch *G* is much more like that of *A*, both in size and in rise and fall. The tree grew on the level, with a N.E. exposure. It has maxima in 1859, '75, '82, '87, '89, and '93 agreeing with those of *A*.

The only parts of the curve that are difficult to under-

stand in comparison with *A*, are the slight falls in 1869, '74, and '80, also a rise, instead of a fall, from 1870 to 1872, and in 1891, but as the positions and exposures of the trees were so different, the latter, situated low down in the valley, would be more affected by frosts than the trees on the hillsides.

When we compare the curves of the three larches *A*, *F*, and *G*, we find that they have maxima in common in 1859, '75, '82, '89, and '93; but the only minima which strictly agree are in 1888.

The Norway spruce, *B*, shows a good curve. It is known to be a tree which thrives best in a moist atmosphere, and with a certain amount of shade.

The increment increased from 1856 to 1857, as the former was a remarkably cold season, and the latter a very fine one, with rainfall about the mean.

The fall and rise from 1857 to 1861 corresponded with the drought of those years. The warm, humid, rainy season of 1861 produced the largest increment of the 38 years.

The fall from 1861 to 1866 agreed with a dry period. The rise of 1867 occurred during greater rainfall and humidity, and with sunshine below the mean.

The rise begun in 1867 was maintained until 1870, when the seasons were warm and humid, although the rainfall was below the mean.

The fall of 1871 was probably due to low summer temperature. The rise from 1871 to 1875 was due to very wet but warm summers; and although 1875 was drier than any of the preceding five years, yet the warm summer maintained the growth, and the rainfall and humidity were only slightly below the mean. The summer rainfalls of 1872–73 were probably too great even for the wellbeing of a moisture-lover like spruce.

The fall from 1875 to 1878 was due to the drought of 1876 and the very low summer temperature of 1877.

The better conditions of 1878 prevented a further decrease of increment, and helped to counteract the influence of the cold summer of 1879, when there was a slight rise over the increment of 1878.

The higher temperature of 1880 caused an increase in the increment, and the rainfall was only a little under the mean.

The fall of 1881 corresponds with a cold and relatively dry summer.

The gradual rise from 1881 to 1886 occurred during a period of great summer rainfalls and low temperatures.

The slight fall in 1887 and 1888 agreed with a period of drought.

The rise in 1889 and 1890 occurred during moister seasons than the preceding two.

The fall in 1891 and 1892 was probably due to the greater cold of the summers, to a gradual decrease of humidity, and partly to the low rainfall of 1892.

The slight rise in 1893 was mostly due to the high summer temperature, while sunshine, rainfall, and humidity also increased from 1892.

The curve of Scots pine, *E*, agrees with larch *A*, in having maxima in 1859, '80, and '93, and minima in 1885 and 1892; and with spruce *B*, in having maxima in 1857, '63, '73, '80 '90, and '93, and minima in 1858, '60, '78, '85, and '92.

This seems to show that Scots pine agrees more closely in its requirements of meteorological conditions with spruce than with larch.

The tree was 100 years old at the section, and at that age the influence of the external conditions are not so quickly perceptible in the annual rings as they are when the tree is only 50 or 60 years old.

As the curve has no striking rise or fall it will be sufficient to mention only the chief periods of the tree's growth.

The warm dry years 1857 to 1859 account for the maintenance of the increment, and the warm summer of 1857 corresponds with the maximum in the curve. The cold, wet, and cloudy summer of 1860 caused a fall; the warm summer of 1861, in spite of increased rainfall, caused a rise, which was maintained through the dry period until 1866; although the summers of 1862–63 were cold, the sunshine was much above the mean. The cold, wet, and cloudy year 1867 caused a very sudden fall—the most rapid fall in the whole curve.

There was a slow but gradual rise until 1876 during a period of warm, sunny summers. The heavy summer

rains of 1872, '73, and '74 do not appear to have affected the rise, except that without so much rain the rise might have been greater.

The fall from 1876 to 1879 occurred during a period of heavy rainfall, low sunshine, and low temperature. The dry, warm, sunny summer of 1880 caused a rise; then came a fall until 1885, during which time sunshine and temperature were low, and rainfall high.

The rise from 1885 to 1890 occurred during a drier and warmer period.

The fall in 1891 and 1892 agreed with that of most of the other trees, as also did the rise of 1893. Scots pine agrees with larch in preferring warm, sunny seasons, but it also grows well in wet seasons, provided they are also warm; and cold, wet seasons hinder its growth considerably. Spruce prefers moist seasons; it does not stand prolonged drought, and even a warm, sunny period is against its growth, if at the same time the rainfall is low.

I have to thank Mr. Percival C. Waite for helping me with the calculations; Mr. William T. Finlayson, my assistant, for part of the drawings and colouring of the diagrams; and Mr. William M. Miller, my laboratory assistant, for valuable assistance in drawing and colouring the diagrams and curves.

APPENDIX.

"It is beyond doubt that the mean temperature is of much less importance to forest trees than the extremes of temperature which occur in a particular locality, more especially during the growing period."—Schlich's "Manual of Forestry," 1st ed. vol. i. p. 36. According to Gayer—"Der Waldbau," by Dr. K. Gayer, 1882—the relative heat requirement is greatest in Scots pine, less in spruce, and least in larch.

"Trees suffer, as a rule, little from winter frosts within the region of their natural distribution, but frost which occurs during the growing season may do considerable damage, especially during spring."—Schlich, vol. i. p. 115.

"The late frosts in spring and the early frosts in autumn often occasion very considerable damage, especially to young growth. Danger from frost is greater on plains than in hilly tracts; greater on S. and S.E. exposures than on N. and W.; greater in localities protected from the wind than in those where currents of air have free play; greater in a dry state of the atmosphere than in a moist."—Nisbet's "British Forest Trees," p. 27.

"In the case of evergreen conifers, the limitation of growth towards the north, or on lofty mountain tracts, is not so much due to the actual degree of cold to which they are exposed, but is principally caused through dry winds on sunny days in winter stimulating transpiration through the leaves at a time when the roots can draw no fresh supplies of moisture from the frost-bound soil. Owing to the loss of moisture contained in the tree, the foliage becomes yellow and sickly, the growth impaired, the spines or needles are shed, and, finally, the death of the tree ensues. This phenomenon is most distinctly noticeable after long dry winters with comparatively frequent sunshine."—R. Hartig, "Lehrbuch der Baumkrankheiten," 2nd ed., 1889, pp. 104, 261; transl. by Nisbet—"British Forest Trees," p. 25.

"The differences found in the growth of trees in different years represent a record of the influences of the seasons upon the growth of trees. Spruces make their greatest growth in seasons that are generally of a wet character. Larch and pines invariably make their greatest growths in seasons of a moderate character. In very dry seasons spruces make comparatively small growth if they are not on a soil of a cool-bottomed nature."—"The Forester," by James Brown, LL.D. (6th ed.). Enlarged and edited by John Nisbet, D.Œc. Vol. ii. p. 357.

"On taking a general view of the ten years' observations, one of the most striking results is the great variation in the annual increase of the vast majority of the trees, indicative, it is to be presumed, mainly of a marked sensitiveness to the varying meteorological conditions of the different seasons through which they have passed."—David Christison, M.D., F.S.A. Scot., "Trans. Bot. Soc., Edin.," vol. xvii. p. 393 (1889).

"The depressing effect upon girth-increase of disease or injury may be prolonged for years after the date of the disease or injury, even when the affected trees appear perfectly healthy. . . . A question of much interest is whether trees which have suffered a prolonged depression in their girth increase, from low winter temperatures or other causes, will eventually recover their normal rate."—Christison, loc. cit.

"Generally the girth-increase is more evenly distributed over the season in the Coniferæ than in the deciduous species."—Christison, "Trans. Bot. Soc., Edin.," vol. xix. p. 331 (1892).

EXCURSION OF THE SCOTTISH ALPINE BOTANICAL CLUB TO KILLIN IN 1897. By WILLIAM CRAIG, M.D., F.R.S.E., Secretary.

(Read 13th January 1898.)

The Excursion of the Scottish Alpine Botanical Club in 1897 was to the Breadalbane Mountains, in the neighbourhood of Killin, a district that always well repays the botanist to visit. On Monday, 2nd August 1897, the following members of the Club met in John Cameron's Hotel, Bridge of Lochay, Killin, and were most comfortably accommodated by Miss Cameron:—William B. Boyd, Presi-

dent, Rev. Dr. Paul, Rev. Mr. Gunn, Dr. Charles Stuart, Robert Lindsay, George H. Potts, A. Somerville, B.Sc., and Dr. William Craig, Secretary. This was the hotel in which the Club was originally constituted on 10th August 1870, under the Presidency of the late Professor John Hutton Balfour. There was also present, as a visitor, Mr. F. C. Crawford. The members of the Club travelled to Killin in a fine saloon, kindly provided by the officials of the Caledonian Railway.

A business meeting of the Club was held in the evening, when Captain F. M. Norman, R.N., was elected an honorary member, and Dr. David F. Playfair, of Bromley, was elected an ordinary member. Dr. Playfair is well known as an able and zealous botanist.

Tuesday, 3rd August 1897.—The day was again excessively hot and sultry, and so mountaineering could only be performed under difficulties.

After an early breakfast, we drove in a waggonette on the way towards Lawers, as far as Carie, and ascended Ben Lawers, going up the east side of Allt-an-Tuim-Bhrie, the burn which comes down to Loch Tay between Ben Lawers and Beinn Glass. We ascended the corrie on the west side of the mountain, and, after examining the rocks at the summit, descended by the ridge to Lawers Inn, where we found our conveyance awaiting us.

Our member, Mr. A. Somerville, sent specimens of the Hieracia and Salices, collected during this excursion, to the Brothers Linton, who kindly named them for us. Other plants, such as *Alsine rubella, Sagina nivalis*, etc., were verified by Bennett, of Croydon. The members of the Club are greatly indebted to the Brothers Linton, and also to Mr. Bennett, for the assistance rendered in naming the plants. I must also acknowledge the great assistance I have derived from Mr. Somerville in preparing a list of the plants.

Among the plants collected may be mentioned—*Thalictrum alpinum*, L.; *Cerastium alpinum*, L., plentiful; *Alsine hirta*, Wormsk., on rocks near the summit; *Sagina Linnæi*, Presl. (*S. saxatilis*, Wimm.); *S. nivalis*, Fries, on bare rocks near the summit. The *Alsine hirta* and *S. nivalis* were first picked by Mr. Lindsay, and afterwards by the other

members of the Club. *Saxifraga oppositifolia*, L.; *S. nivalis*, L.; *S. cernua*, L., on the well-known station near the summit; *Epilobium alsinefolium*, Vill.; *E. alpinum*, L. (*E. anagallidifolium*, Lamk.); *Erigeron alpinum*, L., near the Gentian rocks; *Gentiana nivalis*, L., one specimen with nine flowers; *Myosotis alpestris*, Schmidt, in beautiful flower; *Plantago maritima*, L.; *Salix reticuluta*, L., very beautiful; *Tofieldia palustris*, Huds.; *Carex atrata*, L.; *C. pulla*, Good.; *Aspidium Lonchitis*, Sw.; *Botrychium Lunaria*, Sw. Lawers Inn was reached about 6.30 P.M.

At Lawers Inn we met Mr. C. Druce, of Oxford, a distinguished botanist, who had come north to search for a rare Carex on Ben Lawers. We had a pleasant drive home to Bridge of Lochay, and were home in good time for dinner — all greatly delighted with this first day's excursion. In the evening Mr. J. A. Terras, B.Sc., joined the Club as a visitor.

Wednesday, 4th August 1897.—The day was again hot and sultry in the extreme. There was not a breath of wind, and a burning sun in a cloudless sky; and certainly the Club never experienced a day more trying for mountaineering. After a drive of ten miles up the valley of the Lochay, we walked several miles farther up the valley till we reached the foot of Beinn Heasgarnich, a mountain situated between the Lochay and the Lyon, and 3530 feet in height. Of the party of ten, only eight attempted the ascent of the mountain, and of these eight, two felt the heat so oppressive that they left the others, and afterwards went to Craig More, a mountain 3305 feet in height, situated to the south-west of Beinn Heasgarnich. The remaining six persevered, and in due time reached the top of Beinn Heasgarnich, and afterwards botanised the rocks on the Glen Lyon side of that mountain.

Among the plants collected may be mentioned—*Dryas octopetala*, L.; *Saussurea alpina*, DC.; *Loiseleuria procumbens*, Desv., in fruit; *Pyrola rotundifolia*, L.; *Gentiana campestris*, L., var. *alba*, in great abundance near the Lochay ——; *Veronica serpyllifolia*, L., var. *humifusa*, Dicks., in fine flower; *Bortsia alpina*, L.; *Salix Lapponum*, L.; *S. reticulata*, L.; *Juncus triglumis*, L.; *J. biglumis*, L., on both sides of the mountain; *J. castaneus*, L., on the

Glen Lyon side of the mountain; *Carex pauciflora*, Lightf.; *C. curta*, Good.; *C. atrata*, L.; *C. vaginata*, Tausch.; *C. capillaris*, L.; *C. flava*, L.; *C. pulla*, Good.; *Phleum alpinum*, L. The party who went to Craig More gathered many good Alpine plants, including—*Dryas octopetala*, L.; *Epilobuim alpinum*, L.; *Galium boreale*, L.; *Saussurea alpina*, DC.; *Bartsia alpina*, L.; *Salix reticulata*, L.; *Carex atrata*, L.; and *Woodsia hyperborea*, Br.

The various members of the party met the conveyance about six o'clock, and after a pleasant drive of two hours reached our hotel in safety, but all very tired. On the way home we heard thunder rumbling in the distance, and had just reached our hotel when a severe thunderstorm broke over Killin, and the rain came down in torrents. A very large cloud overshadowed the village, and had the appearance of ink. The storm lasted till past midnight. The lightning was most vivid. This thunderstorm extended over a large part of Scotland, and was specially severe in the region of Loch Tay. As there was no mist on the mountains, the visitors staying at Lawers Inn had magnificent views of Ben Lawers and of Loch Tay. The storm was severely felt in Edinburgh, and one house in Lauder Road was set on fire by the lightning.

Thursday, 5th August 1897.—The day was again warm and sultry, and occasionally during the day distant peals of thunder could be heard. The excursion to-day was again to Ben Lawers, especially to the rocks above Lochan a Chait. We drove as far as Lawers Inn, where we again met Mr. Druce, of Oxford, who showed us specimens of a Carex which he had gathered on the previous day on Ben Lawers, and which Carex he has thus described in the "Annals of Scottish Natural History" for October 1897: "Carex from Ben Lawers.—I have gathered a sedge on Ben Lawers that is either *Carex helvola* or *C. macilenta*."

Seven of the party ascended Ben Lawers, and the other three botanised the sides of Loch Tay. Mr. G. C. Druce, of Oxford, accompanied the party who went to Ben Lawers.

Among the plants collected on Ben Lawers may be mentioned—*Chrysosplenium alternifolium*, L.; *Epilobium alpinum*, L.; *Cornus suecica*, L.; *Adoxa Moschatellina*, L.;

Hieracium prenanthoides, Villars; *H. cerinthiforme*, Backh. in lit.; *Myosotis alpestris*, Schmidt; *Salix Myrsinites*, L.; *S. Arbuscula*, L.; *S. reticulata*, L.; *Juncus triglumis*, L.; *J. biglumis*, L.; *J. castaneus*, L.; *Carex pulla*, Good.; *Phleum alpinum*, L.; *Avena pratensis*, L., var. *alpina*, Smith; *Sesleria cærulea*, Scop.; *Aspidium Lonchitis*, Sw.

Dr. Paul also picked two specimens of a peculiar looking Carex, which we believe to be the same as that found by Mr. Druce, and which he (Mr. Druce) believes to be *Carex helvola*, or *C. macilenta*.

The party who botanised the side of Loch Tay saw many interesting plants, among which may be mentioned—*Galium boreale*, L., in great abundance at the very margin of the loch; *Littorella lacustris*, L., abundant and in beautiful flower; *Rumex alpinus*, L., on the well-known station for that plant.

On driving along to Lawers Inn in the morning, we counted *ten* of the telegraphic posts between Killin and Lawers damaged by lightning, some of them shattered to pieces. We had a pleasant drive home to Bridge of Lochay, and got to our hotel just as the rain was coming on.

Friday, 6th August 1897.—Our new member, Dr. Playfair, joined the party this morning. The Excursion to-day was to the rocks to the west of Lochan-na-Lairige, a small loch 1597 feet above sea-level, and lying in the pass on the side of the road which leads from Loch Tay to Glen Lyon. The morning was dry, but dull. We drove in two conveyances as far as the loch, and as the rocks came down to the very margin of the loch, we were thus driven close to our botanising ground. Shortly after reaching the rocks rain came on, and soon became very heavy. This was very unfortunate, for the rocks were very promising. We tried occasionally to shelter ourselves under the shadow of the rocks, but after waiting two hours or so, and being well drenched, we resolved to return to Killin. As our conveyances were at the stables of the shooting tenant, we sent a message for them to be brought up to the loch, and we all returned to our hotel early in the afternoon. It was well that we did so, for during the afternoon and evening the rain came down in torrents.

Among the plants collected to-day may be mentioned—*Draba incana*, L., very large; *Vicia sylvatica*, L., on rocks above the loch; *Potentilla salisburgensis*, Hænke, in fruit; *Saussurea alpina*, DC.; *Hieracium anglicum*, Fr.; *H. cerinthiforme*, Backh. in lit.; *H. prenanthoides*, Vill.; *Juncus castaneus*, L.; *Carex atrata*, L.; *Avena pratensis*, L., var. *alpina*, Smith; *Woodsia hyperborea*, Br.,—this fern was gathered both by Dr. Paul and Mr. Gunn.

Saturday, 7th August 1897.—To-day the members of the Club returned home. The Caledonian Railway officials again honoured the Club by providing a fine saloon carriage to bring the members from Killin to Edinburgh. Thus ended a most pleasant and, at the same time, a very profitable excursion.

It was, however, a great disappointment that neither on Beinn Heasgarnich nor on Ben Lawers did the members pick *Carex ustulata*. It is known to grow on the first of these mountains, and on Ben Lawers it was discovered by the famous botanist Don in 1810, and was not again gathered on Ben Lawers till 1892, when it was picked by Dr. Paul during an excursion of this Club. On both days, however, the members had far too little time to search properly for the plant.

APODYA LACTEA, CORNU (LEPTOMITUS LACTEUS, AGARDH), one of the SAPROLEGNIACEÆ. Described by ROBERT TURNBULL, B.Sc., Lecturer on Botany, School of Medicine of the Royal Colleges, Edinburgh. (With Plate.)

(Read 10th March 1898.)

During January 1898 I received specimens of *Apodya lactea*, from the Ringorm Burn, which flows into the Spey. The fungus was found attached to stones, decaying branches, grass, etc., in the bed of the stream, below the point where the effluent from a distillery entered. I also procured specimens from the Aberlour Burn; and the fungus is common in the Fiddich,—both streams receiving discharges from distilleries, and flowing into the Spey.

I am informed by Prof. J. W. H. Trail, of Aberdeen University, that the *Apodya* is found in the river Don, below certain paper works.

G. Massee, of Kew Gardens, states in the "British Fungi" (*Phycomycetes* and *Ustilagineæ*) that the fungus is found in ditches and rivers, attached to wood, aquatic plants, etc., and that it is not uncommon.

Prof. E. Warming, of Copenhagen University, says (p. 108, "Systematic Botany," Engl. transl. by Prof. Potter), that *Leptomitus lacteus*, Agardh, is frequent in the waste matter from sugar factories.

Since the fungus appears in streams which receive organic discharges, it must be regarded as an index of such discharges; in other words, it is an index of pollution.

Massee describes it (p. 129, op. cit.) as "forming tassel-like waving tufts, attached at the base, dirty white, and slimy; filaments up to 5 cm. long, and 6–12μ thick, constricted at intervals, dichotomously branched, flaccid."

My observations confirm all these characters, except the thickness of the filaments and the nature of the branching. The average thickness of the filaments is 10–15μ; the young branches are about 5μ thick; the older branches just below the constrictions may be as thick as 30μ, while in one instance I found the width below the constriction to be 40μ.

The branching in every case is lateral, and not dichotomous as stated by Massee, but the branches ultimately become as vigorous as the parent shoots, and simulate true dichotomy.

While the branches mostly arise singly, I have found and figured opposite branches, which are rare. The ordinary vegetative branches always arise immediately below the constrictions, as shown in the photographs.

Schenk, in his "Handbuch der Botanik," Band iv. fig. 62 p. 374, shows papillæ arising laterally from the middle of the zoosporangia; these are the papillæ by which the germinated zoospores ultimately escape.

Saccardo describes the fungus as follows:—"Hyphæ constricted at regular intervals, sparingly branched; zoosporangia formed from the terminal portions of the branches,

one or several superposed; zoogonidia maturing within the zoosporangium and not escaping until after germination."—*Leptomitus*, Agardh, Syst. Alg. p. 50; Sacc. Syll. vii. p. 265.

The only exception to this description is that the constrictions occur very irregularly.

When the fungus is alive, its highly granular protoplasm is in a state of very active circulation. Spherical or polyhedral cellulin-grains are found, usually singly, scattered throughout the filaments, but chiefly at the constrictions, and are mostly large enough to fill up the diameter of the filament.

"The cellulin-grains, discovered by Pringsheim in the hyphæ of various *Saprolegniaceæ*, have sometimes the form of round or polyhedral plates and are sometimes globular, and often show evident stratification. They are not coloured by iodine solutions, and are even insoluble in concentrated caustic potash solution, but soluble in concentrated sulphuric acid and in a solution of zinc chloride. Nothing is known of their chemical constitution."—(Botanical Microtechnique, by Dr. A. Zimmermann, Engl. transl. by Humphrey, p. 231; *vide* "Ueber Cellulinkörner, Ber. d. D. botan. Ges. 1883, p. 288,—Pringsheim.")

To preserve the fungus, and at the same time stain it for microscopic examination, I placed it in a one per cent. solution of osmic acid for twenty-four hours; this darkened the granular protoplasm and the cell walls, and thus improved them for photographic purposes, but the cellulin-grains were only very slightly darkened. The cellulin-grains seem to have a denser external layer and a less dense central portion, for the outer layer has the appearance of a thick cell-wall.

Although the chemical constitution of these cellulin-grains is unknown, it is probable that they are forms of reserve food material.

The zoosporangia seem to be developed as terminal shoots. The end of a hypha becomes densely granular and opaque, reaching a length of $200-220\mu$ and a breadth of $15-20\mu$, then a constriction appears just behind the apex, and growth takes place both in front of and behind

the constriction; the older portion may ultimately lengthen to 260μ, while the apical portion may give rise to another constriction just behind its apex, and thus three superposed zoosporangia are formed. I have found two commonly, three rarely, superposed. At the constriction separating adjoining zoosporangia the passage becomes so narrow as to prevent the escape of zoospores from one sporangium into the other.

The zoospores (or zoogonidia) do not escape from the zoosporangia, but germinate inside the zoosporangia before escaping; the germinated zoospores are mostly spherical, and average 13μ in diameter.

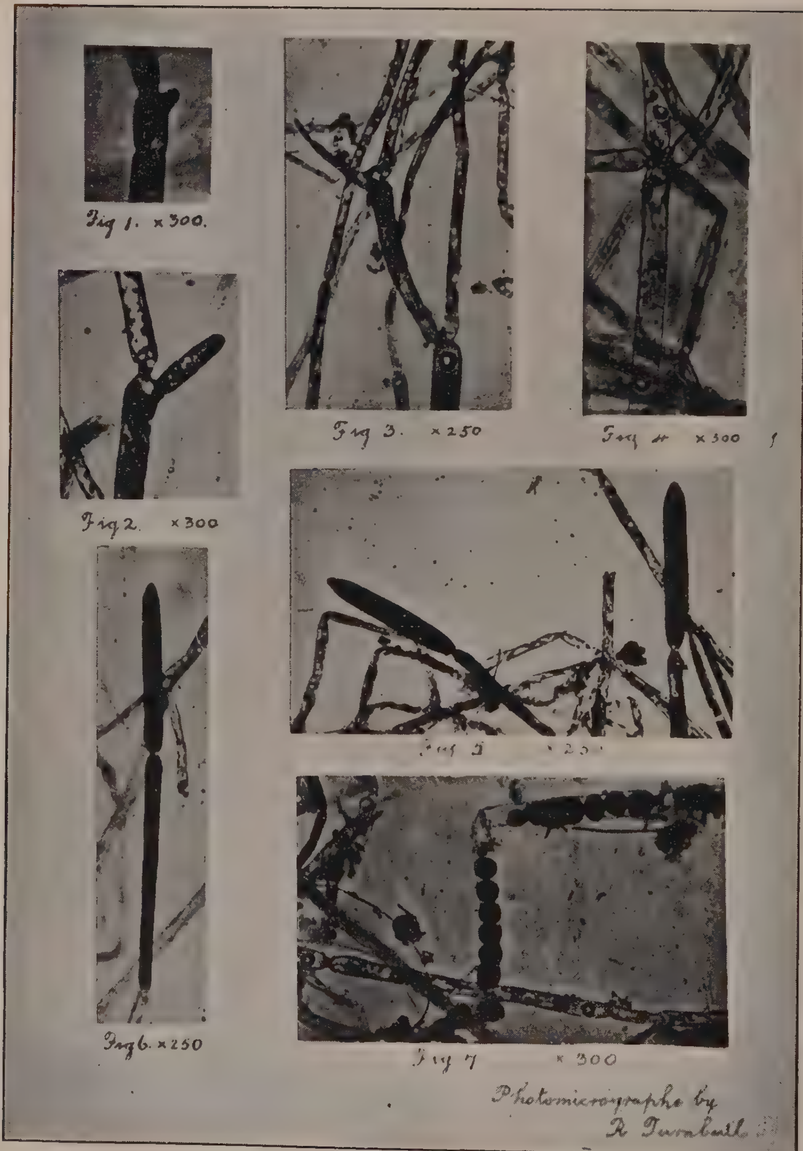
I have not observed the sexual stage in any of the material examined. *Apodya lactea*, Cornu, is a saprophyte throughout its whole life, and thus differs from *Saprolegnia ferox*, which represents the most closely related genus in the same order, *Saprolegniaceæ*. *Saprolegnia ferox*, the cause of salmon disease, is normally a saprophyte, living on dead fish, etc., but it is also a facultative parasite, and lives on the tissues of the living fish.

The food of *Apodya* is organic matter, both nitrogenous and carbonaceous; the fungus, in common with all the *Phycomycetes*, to which sub-class it belongs, is a rapid grower, and also as rapid in its decay.

Such a fungus, the existence of which depends on pollution, absorbs some of the organic matter from the water, but sooner or later it gives off decaying strands which readily putrefy in passing down the stream. It has been stated that the fungus floats on the surface, but I have found that, whether living or dead, it always sinks in still water.

In conclusion, the action of *Apodya* is threefold:—It removes oxygen from, and gives off carbon dioxide to, the water, during its own life; it takes the place of green plants which act beneficially by removing carbon dioxide from, and returning oxygen to, the water; it removes temporarily some of the organic polluting matter, and returns it to the water afterwards in a putrescent condition during the decay of its cast-off strands.

The photomicrographs have been taken from specimens mounted permanently in osmic acid, and for the careful



APODYA LACTEA, CORNU.

developing of these I am indebted to my laboratory assistant, Mr. Wm. M. Miller.

Explanation of figures of *Apodya lactea*, Cornu:—

1. Lateral branch beginning below a constriction.
2. Lateral branch lengthening.
3. General appearance of fungus, showing branching, constrictions, granular protoplasm, and two highly refractive cellulin-grains (near the foot of the figure).
4. Rarer form of opposite branches. Observe large cellulin-grain at the base of the main filament, and another above the constriction.
5. Two pairs of zoosporangia.
6. Two zoosporangia, superposed, showing attachment to filament at base.
7. Old zoosporangium, showing germinated zoospores (zoogonidia) internally. Observe several cellulin-grains in the other filaments.

The Relation between the Colour of Daffodils and the Composition of the Soils in which they are grown. By A. P. Aitken, D.Sc.

(Read 10th March 1898.)

At a recent meeting of the Society a discussion arose regarding the depth or brilliance of colour assumed by the same species of plant according to a variety of external circumstances, such as the height above the sea-level, the latitude, and the exposure. It seemed probable that the quality of sunlight which reached a plant would be most likely to cause colour differences of the kind in question. It was the experience of members of the Society accustomed to mountaineering that the colours of many of the commoner flowers found at all altitudes were brighter the higher the level at which they were grown. It seemed probable that this might be attributable to the different quality of light at higher levels where the sun's rays were filtered through a thinner stratum of atmosphere. It is well known that the atmosphere in our latitude not only absorbs fully one-third of the total light that should reach it from the sun, but that it also exercises a selective function in absorbing some of the light rays more than others, viz. those towards the violet end of the spectrum. That such a sifting of light might affect the intensity of

the colour of flowers was very natural to suppose, but Mr. Barr, who happened to be present at the discussion, was of the opinion that the character of the soil had much to do with colour brilliance. He had noticed that daffodils grown in certain districts exhibited special shades of colour, and thought it probable that a chemical analysis of the soils of these districts would show peculiarities that might explain the differences observed, and perhaps shed some light on the relation of colour in plants to soil composition. I offered to make analyses of soils where daffodils grew, showing the characteristic tints, if he would send me carefully taken samples. In due course there arrived three samples of soil, the description and analyses of which were as follows :—

No. 1. Soil from the Asturias, where the *Narcissus pallidus*, præcox, grows of a pale sulphur colour.

No. 2. Soil from Galicia, where the hybrid *Narcissus Johnstoni*, Queen of Spain, grows of a clear yellow colour.

No. 3. Soil from the mountains of Leon, where *Narcissus minimus* grows of a full yellow colour.

	DRIED AT 100° C.		
	No. 1.	No. 2.	No. 3.
Organic matter	5·27	10·10	13·54
Phosphoric acid	·04	·09	·21
Potash	·08	·31	·26
Lime	·05	·17	·21
Magnesia	·10	·47	·30
Alumina	·86	5·38	4·40
Peroxide of iron	1·13	4·50	5·35
Nitrogen	·21	·27	·32
Nitric acid	·0009	·0045	None.
Stones, roots, etc.	40·60	7·67	17·21

If we regard these soils from an agricultural standpoint—that is to say, from the point of view of fertility or capability of producing an abundant growth—they are seen to present great differences. No. 1 would be classified as a very poor soil, No. 2 as a soil of medium quality, and No. 3 as a rich soil—in respect of those substances which are chiefly required for the nourishment

of plants, namely, phosphoric acid, potash, and nitrogen, and also in two ingredients which are of great importance in promoting fertility, namely, organic matter and lime.

The question before us, however, is not one of relative fertility, which has to do with the number of bulbs that can be grown per acre, but only one of quality as regards the matter of colour. It is evident that the poverty of soil No. 1 is due in great measure to the large proportion of stones in it. It would be necessary to remove the excess of these in order to compare the actual fine soil contained in this sample with the others. In the subjoined tables are given the analyses of the fine soils from which the stones have been altogether removed.

	Dried at 100° C.		
	No. 1.	No. 2.	No. 3.
Organic matters	8·87	11·00	16·36
Phosphoric acid	·07	·10	·25
Potash	·14	·34	·31
Lime	·08	·18	·26
Magnesia	·17	·51	·39
Alumina	1·45	5·84	5·32
Peroxide of iron	1·90	4·88	7·67
Nitrogen	·35	·30	·39
Nitric acid	·0015	·005	None.

Seeing that the lightest coloured daffodils were grown on soil No. 1, the deepest coloured on soil No. 3, and that those on soil No. 2 were of an intermediate shade, it is evident that if these differences were due to differences in the chemical composition of the soils, we must look for the explanation in the amounts of these constituents that either increased or decreased regularly in proceeding from soil No. 1 to soil No. 3. We see that, in fact, the organic matter, the phosphoric acid, the lime, and the peroxide of iron all varied in that order, while none of the other constituents varied regularly in the opposite direction, so that we are led to infer that the increasing depth of colour may be due to the greater amount of one or more of these four constituents. It may be that only one of the four was concerned in producing the colour change; but if so, we

are left without any clue as to which of them it was. In order to determine that point, a set of experiments would be required, with soils artificially prepared, in which each of these constituents in turn was made to predominate, or in which each of them in turn was deficient. It would be easy to prepare soils of that kind and to grow bulbs in them, but it would, perhaps, be a long time before any definite results could be obtained, for the colour differences observed are probably the result of a long course of breeding through many generations of plants, and the rate of change would be slower in the case of bulbs than in that of most plants, for bulbs contain within them a large store of the nutrition required for the production of flowers, and they are not so dependent as most other plants upon the immediate supply of food they are able to abstract from the soil.

It is probable that an analysis of the bulbs themselves would lead more rapidly to the solution of the problem, for it is not so much the quantities of the various food constituents contained in the soil, as the amounts of these that the plants are able to assimilate, which determines the effects they are able to produce. It is evident, therefore, that the analyses here given form only the beginning of what, if not a very important, is at least a very interesting inquiry.

NOTES ON HYBRID VIOLAS. (With Specimens.) By JAMES GRIEVE, Redbraes Nursery.

(Read 12th May 1898.)

Mr. Grieve gave a few notes on various hybrid violas produced by him during thirty years of careful cross-breeding, using as seed-bearing parents *Viola lutea*, *V. amœna*, *V. stricta*, *V. cornuta*; and as the male parent the improved forms of *V. tricolor*. Every shade of these distinct colours—yellow, white, blue, and purple—were to be found, as well as a number of beautifully striped and spotted forms, which, when better known, will be very ornamental border or rock garden plants. All are

quite hardy, with free branching dwarf habits of growth, and almost perpetual flowering. Many of them are also very fragrant.

ASTRAGALUS ALPINUS ALBUS. By ROBERT LINDSAY.

(Read 14th July 1898.)

Astragalus alpinus is one of the rarest and most beautiful of our Scottish Alpine plants. Previous to 1884, there were only two stations known in Scotland where it was to be found—one at Little Craigendal, in Aberdeenshire, the other at the head of Glen Doll, Clova, in Forfarshire. A third station was discovered by Mr. Patrick Neill Fraser in September 1884, on Ben Vrackie, a mountain near Pitlochry, in Perthshire, and it was at this station where the white variety that I now exhibit was found. It is very remarkable how *Astragalus alpinus* was so long overlooked on so popular a mountain as Ben Vrackie, as from its abundance at this station the plant must have been growing there for a very long period. The rocks, for a considerable distance, are quite covered with *Astragalus*, and among the débris at the foot of the rocks, the herbage consists almost entirely of *Astragalus alpinus*, which in places forms a carpet as smooth as a bowling-green, probably by the plant being cropped and eaten by sheep.

It was here, at the foot of the rocks, that I dug up a few plants to grow, at the end of June 1896. I searched the rocks higher up, and obtained a few flowering specimens, but they were all typical *alpinus*, and I had no idea that the plants I dug up were anything different from the ordinary type till they came into flower a few weeks ago, and I was not a little surprised to find two or three separate patches of a white variety intermixed with the ordinary pale blue form. The plants are now forming an abundance of seed.

There is in cultivation, and has been for a long time, a white variety of *Astragalus hypoglottis*, but how it originated I know not. There is no record, so far as I know, of a white variety of *Astragalus alpinus* having been known to exist previously, and I therefore submit it to the Society.

HYBRID VERONICA. By ROBERT LINDSAY.

(Read 14th July 1898.)

The shrubby Veronica which I now show you in flower is a hybrid of *V. amplexicaulis*, a white flowered species from New Zealand, and *V. pimelioides*, a blue flowered species, also from New Zealand. The intermediate hybrid partakes rather more of *amplexicaulis*, except in the colour of the flowers, which are pink instead of white; the leaves of the hybrid are different from *amplexicaulis* in being darker green in colour, and not so large as *amplexicaulis*. It is now in flower with me for the first time, and is one of the best of a batch of seedlings that have yet come into blossom.

TRANSACTIONS AND PROCEEDINGS

OF THE

BOTANICAL SOCIETY OF EDINBURGH.

SESSION LXIII.

Presidential Address.—On the Teaching of Darwin and Pasteur.

(Read 10th November 1898.)

I had intended to give, as an opening address, a paper on the botany of Palestine, but I found it impossible to get the paper ready in time for the opening meeting of the Society. I have therefore put together, some rather discursive remarks, on the teaching of the two great scientists of the latter half of the present century.

Darwinism is founded on three hypotheses—Heredity, Survival of the fittest, and Fortuitous variation.

The third, Fortuitous variation, is often misunderstood.

It has been thought to be opposed to revealed religion. This arises solely from a verbal misconception.

All the operations of Nature—physical, mental, and moral—are, from a human point of view, the work either of law or of chance.

Of chance, if Nature's work is quite unintelligible to man; of law, if it is intelligible or partly intelligible.

The theist knows that all things, whether they appear to him to be the effect of law or of chance, are equally the work of God; but to man, the planets seem to revolve round the sun by law, and comets seem to come into the solar system by chance.

In this sense, and in this sense alone, the word chance, or fortuitous variation, is employed by Darwin.

This is the only rational meaning of the word chance. It was the meaning given by Anaxagoras, who called chance, "a cause unperceived by human logic."

Τὴν τύχην ἄδηλον ἀιτίαν ἀνθεωπίνῳ λογισμῷ.

It is the same sense in which I employ the word when I say, "I met a man on the street, by chance." My only idea is, that I do not know what was the cause of my meeting him. In old times, similar objections were made to the use of the word law; but all educated men now use the words, law of gravitation, law of surface tension, etc.

In the same way, all educated men should use the word chance, in the sense of an effect, the cause of which is unknown to the collective human race.

It follows, of course, that there is no evidence of design in anything done by chance,—design, there no doubt is in mind of the Deity; but evidence of design, to the mind of man, there can be none.

Men see evidence of design in the government of the universe, in the rotation of the planets, in the ebb and flow of the tide, and wherever they have been able to formulate any law.

If there was evidence of design in the variation of organisms, it would leave the realm of chance, and enter that of law. There is, therefore, no difficulty in understanding Darwin, if we use the word chance in its true sense, and never in any other. Chance is an effect whose cause is not known to us.

The glory of Darwin is, that he has not only added many fair fields to the realm of knowledge, but he has also shown us the nature of the boundary wall that limits our kingdom.

That wall, we may never be able to pass; but it is something to know where it stands, and what sort of a wall it is; and this knowledge we owe to Darwin.

Darwin's laws were formulated principally from his studies of animals, and of flowering plants, ferns, and mosses, —three groups of sexual plants. We may ask, How far do his laws apply to algæ and fungi, many of which are asexual?

Life originated in the sea, either on the surface of the deep sea or on the coast, and there is no doubt that the earliest organisms were unicellular algæ, and that the next organisms were also algæ, but multicellular.

The life work of algæ is to fix, by means of sunlight, the carbon derived from the carbonic acid of the ocean water. The algæ probably appeared not very long after the earth's surface cooled below 212°, so as to allow of water existing. For a long time they inhabited a sea of almost equal temperature, for even after the cooling of the earth the equatorial ocean currents would keep the poles warm. At first, reproduction was simply equal division, in obedience to Herbert Spencer's law, of the surface being as the square, and the contents as the cube.

But the law of fortuitous variation was also at work, and as long as the ocean contained but few organisms, it was but little checked by the law of natural selection; so that there would be many varieties, but no species, for it is fortuitous variation that causes varieties, natural selection that makes species, by killing the intermediate forms.

You will observe, however, that these algæ were in very different positions, according as they lived near the equator or near the poles.

At the equator an organism worked, like a day labourer, for twelve hours, and then rested for other twelve.

At either pole, an organism had six months of continuous work, followed by six months of rest, though the temperature in the two places was practically the same.

Reproduction by equal division was all very well at the equator, but things were very different at the poles, and it was there, no doubt, that the more complex forms of algoid reproduction appeared.

I may enumerate the forms of reproduction which now exist among algæ—

1. Simple equal division.
2. Budding.—This may have taken place at the equator as well as at the poles.
3. A resting Spore, which slept for the six winter months, and became an algæ when the summer returned. This is evidently of polar origin.

4. The *Zoospore.*—A free swimming organism, which moves by means of cilia. This also was evidently of polar origin. The zoospore floated or swam away from the dark pole, and, after reaching the equator, and it may be the other pole, became attached and entered on algoid life.
5. Isogamy.—Union of two gamets.
6. Sex.

It is probable that sex did not make its appearance till comparatively late in the world's history, and this for two reasons—(1) because many land plants show no trace of it, so that it probably did not appear among algæ till after land plants left the ocean for the land; (2) by considering what is the use of sex in the economy of an organism.

A glance at the facts will show that the use of sex is to check variation.

When a sport occurs, as in the case of the well-known copper beech, that sport is reproduced by budding; but if the plant were to seed, the seedling would return to the old type. This law is supported by the universal experience of all gardeners. One parent being typical, and the other abnormal, the seedling naturally tends to return to the old or well-established type.

The observations of C. Hurst, on "Hybridisation in Orchids," has thrown considerable light on the nature of sex. He shows that in the case of hybrids among orchids, it is the pollen of the hybrid that is impaired, and that the seed can generally be fertilised by the pollen of either parent. On the contrary, the pollen of the hybrid cannot fertilise a hybrid seed, or a seed of either of the parent plants. This is very like what happens in the case of mules between the ass and mare. The female mule occasionally breeds with a horse or ass. The male mule cannot breed with a mare, a she ass, or a female mule.

Down to the time of Darwin, a species was defined as a group of individual plants, so constituted that the pollen of one individual could fertilise the seed of another.

As this is not the accepted definition of a species at the present day, I must give from the older writers, proofs that it was the accepted definition at the time when Darwin wrote.

De Candolle writes: "We unite as species all those individuals that have so close a resemblance as to allow of our supposing that they have descended from a single being, or a single pair."

Buffon writes: "A species is a constant succession of individuals, similar to, and capable of reproducing, each other."

Cuvier writes: "A species is a succession of individuals which reproduces and perpetuates itself."

Sir Charles Lyall rejected Lamarck's theory of transmutation of species, on the ground that if species were, as Lamarck said, descended from a common ancestor, they would be able to breed together, which was not the case.

Darwin says: "There is no well-marked distinction between races of domestic animals and so-called true species, except that the former are fertile when crossed"; and in "The Origin of Species," page 236, he says: "The fertility of varieties is, with reference to my theory, of equal importance with the sterility of species, for it seems to make a broad and clear distinction between varieties and species."

It is, I think, clear that as long as we quote De Candolle, Buffon, Cuvier, and Darwin as authorities, we ought to use the words they employ in the sense they intended, and not in any other sense.

This especially applies to the word species. In reading and quoting these classic authors, we must understand by species what they understood.

In sexual plants—phanerogams, ferns, mosses, etc.—we can say positively what is a species, and what is not, because we can ascertain whether the pollen of one individual will fertilise the seed of another.

On the other hand, in the group of fungi, called Basidiospores, we can only have provisional species. All we know is, that the spores of *Armillaria melleus* reproduce the plant *A. melleus*; but we do not know whether it is a species or not. It may only be a permanent variety.

The distinction is not a mere verbal one, but most important, for since Darwin's book was called "The Origin of Species," and since we cannot say of any Basidiospore whether it is a species or not in Darwin's sense, all

evidence derived from Basidiospores and asexual algæ must be ruled out of court, and inadmissible in a discussion on Darwinism.

We have assumed that the plants belonging to the great kingdom of the fungi are descended from algæ. When they left the sea, they neither became animals, wandering about devouring vegetables, or other animals, nor did they remain true vegetables, fixing carbon by the aid of chlorophyll and sunlight. They adopted a sedentary life, and became either Saprophytes or Parasites. Those which became Saprophytes had no particular need for sex, and have never developed it. If they could not get one kind of rotting matter, they could get another, and could therefore vary indefinitely. They have, as a rule, become large, and are often beautifully coloured. We know them as Basidiomycetes.

The Parasites, on the other hand, had to adapt themselves to the conditions of life of the plant or animal on which they became parasitic.

To do this, they had to become sexual, for only thus could they preserve a steady permanent type.

We know them as Saprolegnas, parasitic on fish; Entomophthoras, parasitic on insects; Peronosporas, parasitic on plants. All are sexual, and generally small and ugly.

The simplest class of the fungi is that of the microbes—a word meaning minute organisms. They are often called Bacteria, from the name of their best known genus. They exhibit spontaneous division, and have a cellulose wall. They may, therefore, be called Schizophytes.

They have no chlorophyll, and may therefore be called Schizomycetes.

Must we suppose that Darwin's theories apply to these lowly plants?

We must presume that fortuitous variation has occurred, in order to explain how they became fungi, after having been at one time algæ. We must admit in them the law of selection of the fittest, for many of them differ in shape and size, and in the case of some, which resemble each other in all other respects, we find that they have different properties—some harmless to man, some poisonous; but being asexual plants, the law of heredity will not repress

sports. If we are to believe bacteriologists, microbes have the most wonderful capacity for being educated. It is difficult to educate a man—easy to educate a microbe. It is done in every bacteriologist's laboratory. Poisonous microbes are changed into harmless ones.

As I said at the beginning of this paper, the three Darwinian laws, are—Heredity, Survival of the fittest, and Fortuitous variation; but I think I ought to explain what I understand by a law of Nature.

I understand, by a law of Nature, nothing more than a concise statement of the result of many observations.

The observations of many, put in a formula by the wit of one, and submitted to the criticism of all.

I would hold that Newton did not discover the law of gravitation. In reality, he invented it. For man makes discoveries in the regions of percepts. He invents in the region of concepts.

Till the time of Newton, the planets did not obey the law of gravitation, for that law did not exist till Newton invented it to explain complex phenomena.

We call the cycles and epicycles of Ptolemy, an invention of that great astronomer, because we believe that they were not a true explanation. We call the law of gravitation a discovery of Newton, because we believe it was a true explanation. If Newton's law of gravitation had turned out to be incorrect, would that have changed it from a discovery to an invention? Both the Ptolemaic and the Newtonian theories are attempted explanations of phenomena, and I would call them both inventions, though I believe the one to be false, and the other to be true. I would keep the word, discovery, for new things perceived by the senses: invention, for new things thought out by the mind. Of course, those people who believe that the law of gravitation existed before the time of Newton, ought to continue to say that Newton discovered the law of gravitation.

Darwin told us nothing about the origin of life.

The little we know about life, we owe to Pasteur. In 1860, Pasteur discovered the difference between tartrates and racemates, and laid down the magnificent generalisation that organic matter is optically active, and inorganic matter optically inactive.

This great idea was contraverted, and supposed to be refuted, and only this year it has been again proclaimed by thinkers, such as Professor Crum Brown, and Professor Japp. The inferences one may draw are far reaching. Joules's great thought, the conservation of energy, has long been accepted by all. We believe that physical energy in the universe is a constant, never more and never less; just as we believe that its vehicle or plaything, matter, is a constant, never more and never less. What then must we say about life, and its vehicle, optically active matter? We know that in early geologic times, there was probably no life, certainly very little; probably no thought, certainly very little; probably no optically active matter, certainly very little. It follows, therefore, that life and thought can have nothing to do with energy, for energy has not, and cannot have, either increased or diminished, since life and thought came into existence. Energy has, humanly speaking, no beginning and no end. Life and thought have begun on earth, and may end; have increased, and may decrease. If all the human race, and all animals and plants, were to perish, the earth might go on revolving round the sun, as it did before life and thought began, and the amount of energy in the universe would be the same as it is now. It is quite possible that there is no life or thought in the sun, the moon, Venus, or Mars, yet matter is the vehicle of energy there, as it is here.

It may be said that the vital force is only energy transformed, but no one has ever seen motion, or heat, or electricity transformed into life.

No one has ever seen spontaneous generation.

Life has the power of storing up energy in its vehicle, optically active matter; there the energy lies latent, and can be retransformed, by the vital force, from latent into visible energy.

Thought has also the power of stamping on its vehicle, the optically active matter, what it will, and of reading what it has written there.

No doubt energy also has an action on the brain fibres, for energy rules all matter; but in certain kinds of matter, thought also rules.

For many years past, men have failed to notice this.

They have noticed that energy had much to do with brain fibres, and they have fancied that it was the sole ruler; whereas it only holds a divided sway. This is the modern theory of vitalism, which we owe implicitly, though not explicitly, to the teaching of Pasteur. It amounts to this: God has created two types of force in His universe—

1. Energy, which is always acting, always a constant, and which has as its vehicle all matter optically active or inactive.

2. Life, which can only act under certain peculiar conditions, and which has as its vehicle optically active matter. Constancy, and the absence of limitation, are the characteristics of energy. Inconstancy, and limitation, are the characteristics of life.

To explain Nature, we would thus have four independent concepts: Matter, Ether, Energy, and Life.

I may be told all this is mere speculation, and be asked to furnish facts. But we cannot argue about facts, that is to say, about our sensations. We must accept them, and what science has to do, is to try to arrange, and classify them. Science discusses our concepts, whether they make our sensations more intelligible or less.

I claim for vitalism, that it makes some of our sensations more intelligible, than they were a year or two ago, when almost all scientists believed that the brain originated nothing, and that thoughts were a response to environment. In the words of Sir John Batty Tuke, spoken on the 29th July 1898, "All impulses come from without, a fact which must have important bearings on the question of the adjustment of outer to inner relations." When I heard this sentence at the meeting of the British Medical Congress, it appeared to me not to be a fact; and after thinking the matter over, I venture to propound the opposite statement, that most impulses come from within, from the brain of the person himself, or of some other human being, and that only comparatively few, come from without, from inorganic nature—the sun, moon, earth, sea, etc.

On no other hypothesis can I understand what appears to me a fact—the great difference which exists between organic and inorganic nature.

On the hitherto received chemico-physical theories, there has been no explanation of how sap rises to the top of the loftiest trees, in opposition to the law of gravitation, nor why plants, in many other ways, disobey the laws of Nature. By the laws of Nature, I understand the current explanations of phenomena. In this country, the laws of Nature are made by the Royal Society, the British Association, and other scientific bodies. As the sap, which rises from the ground to the top of trees, systematically breaks these laws, it is time for the scientific parliament to pass a revised code, and admit that vitalism is a law of Nature, as well as gravitation, natural selection, capillarity, etc. The laws of Nature are the creation of scientists, just as the laws of England are the creation of politicians, and when a law is not obeyed by subjects, it ought to be altered

A majority of the Royal Society is not infallible, any more than a majority of the House of Commons; and even when these august bodies are unanimous, they are often wrong.

In "Nature," of 27th October 1898, there is an attack on the theory of Pasteur and Japp, by Professor G. Errora, who thinks that the problem of spontaneous generation is not likely to be reduced to the far simpler question of the origin of molecular asymmetry. He thinks a primordial racemic compound, might have spontaneously separated into its two enantiomorphs, somewhere in space, and one of its enantiomorphs come to our planet and the other gone to some other planet. In that planet, the bodies of all living beings would be built up of dextro-gyrose albumens; and the vine-grapes in that planet would yield lævo-glucose instead of dextro-glucose, and the sugar in diabetes would also yield lævo-glucose instead of dextro-glucose. This seems to me to be like elliptical hyperbolic and spherical space, quite unscientific, for it is not a concept attempting to explain observed facts, but an assertion that there may possibly be in space something quite unlike anything on earth,—an assertion which, even the assertor himself admits, it is impossible either to verify or refute.

The theory of Pasteur and Japp has also been attacked by other great men, such as Carl Pearson, Professor Fitzgerald, and Herbert Spencer.

Carl Pearson thinks one asymmetrical molecule might have been formed by chance, and bred others; but to this, Professor Japp replies, that no such case of breeding ever had been seen, and that, as far as has been known, no inorganic molecule has any such effect on another.

Professor Japp also says the mechanical production of single optically active compounds, asymmetric always in the same sense, is not inconceivable, but it is enormously improbable.

Professor Fitzgerald thinks that life might have originated either at the north pole or at the south pole—hence the right- or left-handed structure of an organism.

Professor Japp replies that this experiment, "Can rotation produce asymmetric compounds? has been tried for us by Nature ever since life began on this planet; and the result has been, so far, negative, for we do not find right-handed vegetables at one pole, and left-handed at the other."

On the contrary, in both hemispheres the honeysuckle and most leguminous plants twine with the hands of a watch; the convolvulus and the passion flower, against the hands of a watch.

The old genus, *Jungermannia*, was at one time divided into two sections—

Incubous Jungermannia, with leaf spiral, going against the hands of a watch, such as—*Radula complanata, Frullania dilatata, F. Tamarisci.*

Succubous Jungermannia, with leaf spiral, going with the hands of a watch, such as—*Plagiochila asplenioides, Jungermannia bicuspidata, Lophocolea bidentata.*

These differences are as mysterious, as the fact that the oil from the silver top, stringy bark, *Eucalyptus lævopinea* rotates to the left, and the oil of the messmate, *E. dextropinea*, rotates to the right; but they certainly show that the difference does not depend on the hemisphere in which the plants grow.

Biologists, unfortunately, suppose that they explain a biological problem by handing it over to the chemist, or to the physicist.

In Dicken's novel, Mr. Micawber paid his debts with an I.O.U. The biologist pays his with cheques on the banks

of chemistry and physics; forgetting that their capital is entirely ideal.

All cheques, presented to these banks, are necessarily paid in chemical molecules, ultimate atoms, space, time, and other imaginary coins. Biology can never prosper, till it starts a bank of its own, and pays its obligations with its own notes, printed in its own office; not with cheques on other banks.

In the present state of our knowledge, the conceptual realm of life has so little relation to the conceptual realm of matter, that ideal coin, current in the one country, cannot be taken at par value in the other. The concept matter, with its modes, space, and time, has been invented to explain one group of sense impressions; the concept spirit to explain another group.

Both are ideal existences, yet some biologists suppose that matter has a real existence, not an ideal one; and, not content with this, they suppose that spirit has no existence at all.

This is as if someone were to maintain, that the cause of the phenomena of moonlight is the moon, but as to the phenomena of sunlight, were not only to maintain that the sun is not the cause, but were even to deny that there was any cause at all.

They forget that matter is not a sense impression, but that it is the scientific explanation of a large group of sense impressions, just as spirit is the scientific explanation of another large group.

ON THE FUSION OF NUCLEI AMONG PLANTS: A HYPOTHESIS.

By PERCY GROOM, M.A., F.L.S., Lecturer on Plant Physiology in the University of Edinburgh.

(Read 8th December 1898.)

Little though we know as to the significance of the fusion of the male and female nuclei during the sexual act, we know still less as to the meaning of certain other nuclear unions. Among these latter may be numbered that taking place between the two polar nuclei in the embryo-sac of Angiosperms, concerning which no explanation

yet offered can be deemed satisfactory Le Monnier and, after him, Conway MacMillan (2) hold the view that the nuclear fusion in question is a true sexual act, and that the endosperm represents a small sporophyte which is sister to the main sporophyte. This hypothesis implies that the ovule contains at least one macrospore and one microspore, with their attendant prothallia, and consequently that the carpel is a macro-micro-sporophyll; or it implies that the prothallium is hermaphrodite. Further, unless a number of additional assumptions be made, it denies the homology of the endosperm of the various Angiosperms and the Gymnosperms, either with one another, or else with the female prothallium of the Vascular Cryptogams. Another hypothesis is put forward by G. Mann, who regards the eight nuclei as representing eight female cells, two of which coalesce to form the definitive nucleus of the embryo-sac.

In endeavouring to solve the problem as to the significance of this peculiar fusion of the polar nuclei in the embryo-sac, it is natural to ask, "Do nuclear unions of equally obscure nature occur in plants other than Angiosperms? And, if so, is it possible to draw any general conclusions from a comparison among all the known cases of nuclear unions?" In answer to the first question, it may be pointed out that, thanks to the labours of Dangeard, H. Wager, Sapin-Trouffy, Raciborski, and Harper, definite nuclear unions are known to occur in Ascomycetes, Basidiomycetes, Uredineæ, and Ustilagineæ, between pairs of nuclei inside cells which show no sexual differentiation. The sole explanation hitherto offered in reference to these nuclear unions, occurring in the fungi named, has been that they are sexual acts. The first blow to this hypothesis, so far as it concerns the Ascomycetes, was dealt by Harper (1). His researches on *Sphaerotheca Castagnei* led him to the conclusion that the fusion of the two nuclei in the young ascus is preceded by a nuclear union denoting the true sexual act. In particular, Harper states that the single nucleus of the ascogonium coalesces with a nucleus derived from a contiguous antheridium, whereupon the ascogonium divides transversely to produce a row of cells, and one binucleate cœnocyte which becomes

the ascus after the coalescence of its two nuclei. Harper further states that the young ascus of *Peziza Stevensoniana* contains four nuclei, which, after uniting in pairs, coalesce to form a single nucleus. Whether or no we accept without confirmation Harper's views as to the source of the two nuclei in the ascogonium of *Sphaerotheca*, his researches render it well-nigh impossible to suppose that the fusion of the two or four nuclei in the young ascus is a true sexual act.

It is, in fact, evident that if we regard the union of the nuclei in the young ascus, or in the young embryo-sac, as being morphologically sexual, that is, homologous with the sexual act of the sexual ancestors of these plants, we are involved in a number of improbable and conflicting assumptions.

Still, between the sexual act and these obscure nuclear fusions in the fungi named, and in the Angiosperms, there is one strong resemblance in that the act involves the union of a definite and constant number of nuclei prepared in a definite manner. Does the analogy go any further? If, for a moment, we regard the sexual act as a mere morphological phenomenon, one obvious fact appeals to us, that it takes place at a definite stage in the life-history, namely, the inceptive stage of the individual. The sexual union, involving a fusion of two nuclei, brings with it a break in the life-history of the individual; whereas a mere cytoplasmic union in the higher fungi and vascular plants, at least, is accompanied by no such interruption. Hence the morphological question arises, "Do the nuclear fusions under discussion occur at a definite stage in the life-history of a plant, and, in particular, do they mark the inception of a new generation?" On the other hand, if we regard the sexual act as a physiological phenomenon, the fact that the higher forms of plants and animals are, with a few suggestive exceptions, sexual, is sufficient evidence of the stimulating influence on the race of the sexual act, and presumably of the associated nuclear union. Furthermore, there is a general tendency, exhibited both in classes and in individuals, towards an inverse proportion between, on the one hand, vegetative vigour and circumstances favouring vegetative growth, and, on the other hand,

sexual activity, also the formation of sexual organs, and even of physiologically associated organs. This tendency suggests that the sexual act, with its nuclear fusion, is correlated with the inhibition of vegetative activity, and is calculated to atone for it, both in the race and in the individual. The physiological question therefore arises, "Do the nuclear fusions under discussion, in this respect, bear any analogies to the sexual act, and are they associated with any vegetative degeneration?"

Answering at the same time both these questions, morphological and physiological, the following general conclusions seem probable in reference to the nuclear unions occurring in the ascus, in the basidium, in the spores of Ustilagineæ and Uredineæ, and in the embryo-sac of Angiosperms:—

1. The nuclear union does not represent a true sexual act; it is an interpolation.

2. It takes place in a small generation which is fructificative in development.

3. The generation in which the nuclear fusion occurs is probably degenerate in all cases, and it is natural to suppose that the fusion is correlated with the vegetative degeneracy.

4. In some cases the nuclear union occurs at the actual inception of the generation, and possibly in all cases it occurs at a stage which represents the inceptive stage of the earliest phylogenetic condition of the generation in its particular class. The nuclear union takes place in some cases, and possibly in all cases, inside a cell which is actually or phylogeneticly a single spore.

The succeeding pages are taken up in an attempt to prove these conclusions in detail.

Angiosperms.—The nuclear union takes place in the gametophyte generation, which has lost its power of leading an independent existence, and which is reduced to a mere fructificative individual parasitic upon, and symbiotic with, its predecessor. So far as is known, the nuclear fusion occurs neither among Gymnosperms nor in those Angiosperms whose prothallia (endosperms) develop before fertilisation; it is limited to those flowering plants in which the female prothallium is so degenerate, and in such physiological harmony with its parent, as to develop to a

full extent only after fertilisation. Though the polar nuclei of the embryo-sac do not coalesce at the actual ontogenetic inception of the gametophyte, yet their fusion marks the commencement of the endosperm, that is, the main part, or the whole, of the vegetative portion of the prothallium. We see in the series commencing with the Bryophyta, and culminating in the Gymnosperms, that the development of the gametophyte begins with the production of its vegetative parts. It is only in the higher Angiosperms that the sexual cells outstrip the vegetative parts (leaving the problematic antipodal cells out of count), and it is likewise only in these forms that the nuclear fusion occurs. It is evident that the commencement of the vegetative tissue (endosperm) represents, in a phylogenetic sense, the true inception of the gametophyte of Angiosperms; and the first sign of this inception is the nuclear fusion.

USTILAGINEÆ and UREDINEÆ.—The nuclear union in both these families takes place at the inception of the promycelium, which produces conidia. The young resting spore of *Entyloma* is stated by Dangeard to contain two nuclei, which coalesce before the spore germinates to produce a promycelium with a terminal rosette of conidia. In *Puccinia liliacearum* the teleutospores are arranged in pairs; according to Poirault and Raciborski (1), each young teleutospore possesses two nuclei which unite before it germinates to produce a promycelium with four conidia. But in *Coleosporium euphrasiæ* the teleutospore is four-celled, and each of its spore-cells produces in germination, not a promycelium with four conidia, but a single sterigma with a conidium. We should, therefore, conclude that this four-celled teleutospore, like that of *Chrysopsora*, represents a single teleutospore which has already commenced germination.[1] And Poirault and Raciborski state that the single mother-cell of this four-celled teleutospore contains two nuclei, which coalesce before the transverse septa appear. It is obvious that the promycelium of the Ustilagineæ and Uredineæ is a relatively small and essentially fructificative individual. It will, I think, be conceded

[1] There seems to be no adequate reason for adopting the view, sometimes held, that this four-celled teleutospore represents four spores.

without any detailed discussion of well-known facts in reference to the forms contained in both these orders, that the simplest method of regarding the promycelium is to suppose that it is degenerate, and that it represents a generation which formerly possessed both sexual organs and indefinite conidiophores.

Basidiomycetes.—Dangeard has demonstrated the occurrence of fusions between two nuclei in the young basidia of *Tremella*, *Dacryomyces Calocera*, *Craterellus*, *Nyctalis*, *Polyporus*; and Wager has established the same in *Agaricus* and *Amanita*. The resemblance between this phenomenon and that in the two previous classes is obvious. An unbroken series of forms connects the Uredineæ with the Basidiomycetes. The series commences with plants whose thick-walled teleutospores separate from the mother-plant and rest before germination. The next step in the series is represented by types in which the teleutospores do not rest, but, on the other hand, germinate before being detached from the parent; as types of this may be mentioned *Coleosporium* in the Uredineæ, and the Protobasidiomycetes—Auriculariaceæ, Pilacreæ, Sirobasidiaceæ (4), Tremellaceæ, and Hyaloriaceæ (4),—the basidia of which are septate. The final stage is attained by the Autobasidiomycetes with non-septate basidia. And correlated with the evident fact that the mature basidium represents a promycelium with conidia, and consequently that the young basidium is homologous with a spore (teleutospore), we find that the nuclear union takes place in the young basidium. The series traced up from the Uredineæ shows that the basidium represents a degenerate and fructificative generation parasitic upon its predecessor.[1]

Ascomycetes.—Dangeard has established the occurrence of a union of two nuclei in the young ascus of *Peziza*, *Acetabula*, *Helvella*, *Geoglossum*, *Eurotium*, and *Exoascus*; Harper's observations have already been noticed earlier in this paper. To trace out the precise evolution of the ascus is not so easy as to follow the phylogeny of the basidium. But in this paper De Bary's view is adopted, that there is a distinct alternation of generations in the

[1] This assumption seems in every way more probable than the reverse.

Ascomycetes, and that the ascus-generation is a parasitic sporophyte. This view is supported by Lagerheim's observations on *Dipodascus* (6), Eidam's on *Eremascus*, Harper's on *Sphaerotheca*, and Thaxter's on the Laboulbenieæ (5), as well as by a number of other more dubious instances. The cases of *Dipodascus*, one of the Hemiascineæ, and of *Eremascus*, one of the Protascineæ, both point in the same direction, namely, that already in the archetype of the Ascomycetes, the product of fertilisation was a cell (spore), which germinated fructificatively by giving rise to a single sporangium (ascus).[1] The stages by which a complete generation, with sexual organs and sporangia, might be reduced to a single sporangium, are denoted in the method of germination of the zygospore of *Mucor*, and still better in the germination of the oospore of the Peronosporaceæ. The oospore of *Pythium* may either grow out to form a complete mycelium, with sporangia and sexual organs, or may develop into a sporangiophore, or, finally, may itself become a sporangium. So far as we know, this last method of germination has become hereditary in *Cystopus*. Similarly in the primitive Ascomycetes the whole generation is reduced to a single ascus, and at the inception of this degenerate fructificative generation the peculiar nuclear fusion steps in. Commencing with this condition in the primitive Ascomycetes there exist all stages between a unicellular ascogonium producing only one ascus, to a multicellular ascogonium which, with (?) or without fertilisation, gives rise to many asci. Whether the transverse septation of the ascogonium stepped in before or after the disappearance of any trace of a male organ is a detail; but the ascogonial thread and its branches are together analogous to the suspensor of flowering plants, and the production of a number of young asci in it is comparable to the polyembryony of those Gymnosperms that bear several embryos on one suspensor. Finally, the apparent production on higher Ascomycetes of many asci, quite apart from any ascogonium, may be compared with the adventitious production of embryos from the nucellus of Angiosperms. On the other hand, the production of many

[1] This view has already been supported by Dr. D. H. Scott, in his address to the British Association, 1896.

asci on indifferent hyphæ of lower Ascomycetes may be due merely to the apogamic production of each young ascus which represents a single individual.

Florideæ.—If the view here put forward as to the significance of these nuclear fusions in Fungi and Angiosperms be correct, it might be anticipated that similar unions would occur in other great classes of plants, in forms possessing a small fructificative generation, and exhibiting alternation of generations. So far as I know, only one family of algæ—the Florideæ—provides appropriate examples that have been investigated. And it would be a strong confirmation of my hypothesis if in the Florideæ there occurred definite nuclear unions not representing the coalescence of the nuclei of the male and female cells. Such nuclear unions might occur in connection with the inception of the parasitic and fructificative sporophyte. Schmitz stated that, in a number of Florideæ, not only do the ooblastema-cells unite with auxiliary cells, but definite nuclear fusions also ensue before the production of the carpospores. Comparing this case with these already discussed, it would be natural to conclude that the sporogenous portion of the cystocarp, representing a small fructificative sporophyte, is a degenerate form, and that the alternation of generations in this family is homologous. And, comparing the Florideæ with the Ascomycetes, it is evident that the gradual evolution of the cystocarp has proceeded along lines which are perfectly paralleled by those along which the ascocarp has advanced. Oltmanns (7) has, however, recently denied the occurrence of any nuclear fusions in the Florideæ other than that in the actual sexual act.

The remarks contained in the preceding paragraphs serve to show that the peculiar nuclear fusions taking place in the Ustilagineæ, Uredineæ, Basidiomycetes, Ascomycetes, possibly in the Florideæ, and in the Angiospermæ, show strong physiological and morphological analogies to sexual unions. That there is no homology between the latter and the former is clearly shown in the Angiosperms, Florideæ (?), and probably in the Ascomycetes; for, in these classes, the nuclear fusion in question does not take place at the same stage in the life-history as did the sexual

act in the ancestors, in fact, it is superposed upon and subsequent to the sexual act. Bearing in mind the analogy to the sexual act, we may describe these nuclear unions as being cases of *deuterogamy.*

In seeking to give a deeper and more final explanation of deuterogamy we are met with the initial difficulty that we are quite in the dark as to the significance of the nuclear union taking place during a sexual act. Furthermore, the accentuated difficulty which assails us in our endeavour to conceive of the utility of a fusion between two nuclei formed in one cell (basidium, ascus, or spore), also comes upon us in considering the sexual unions between two adjoining cells belonging to one individual, or in considering the coalescence of the two nuclei in the young auxospore of *Synedra* that has been produced without conjugation with another individual.

The suggestion that the object of the nuclear union is to double the chromosomes is negatived by the occurrence of a double union in the Ascomycetes, and by the fact that in Angiosperms the chromosomes in the endosperm sometimes preserve the half number. In fact, one can only fall back upon the idea that, viewed as mere physiological problems, the coalescence of two nuclei, both in the sexual act [*cp.* Strasburger (3)] and in deuterogamy, is bound up with the nuclear divisions which precede (or possibly succeed) those fusions. The division of a nucleus may afford the latter an opportunity for changing its constitution, for ejecting intra-nuclear protoplasm, and for admitting extra-nuclear protoplasm. And there is much significance in the fact that in all the most carefully investigated cryptogamic examples—Uredineæ, Ascomycetes, and Basidiomycetes—the nuclei before coalescing apparently do eject material which is described as being kinoplasmic or nucleolar in nature.

For the purpose of clearness, the consideration of difficulties and alternative explanations has been postponed to this stage. A few difficulties and other hypotheses are now briefly dealt with.

It might be thought that just as nuclear unions have been suggested between the cells of graft and scion in order to permit of the co-operation of the two symbionts, so in the

cases under consideration the phenomenon is adapted to enable the parasitic generation to work harmoniously with its parent. The hypothesis is negatived by the fact that in the Ustilagineæ, and many of the Uredineæ, the spores become detached from the parent before germinating.

Neither can we suppose that the object of the union is to supply the reproductive cells with nuclei. It is true that where the union takes place in the sporophyte, at any-rate in the fungi, the composite nucleus does supply the spores with their nuclei. But where the union occurs in the gametophyte (*e.g.* Angiosperms), the composite nucleus is not responsible for the nuclear supply of the egg-cell; on the contrary, its rôle is to give nuclei to the vegetative cells.

Again, it might be contended that the nuclear unions on the fungi are essentially connected with a true sexual act, and merely recall the concentration of nuclear material into one spot. This concentration of nuclear material is denoted by Léger and Dangeard's observations on the fertilisation of *Sporodinia*, and by various observations on the oospheres and oospores of Saprolegniaceæ and Peronosporaceæ. In the Saprolegniaceæ, according to Strasburger and Hartog, and in *Peronospora*, according to Wager, a number of nuclei originally present in the oosphere unite to form the single nucleus of the oosphere. But Trow states that there are no such fusions in the Saprolegniaceæ, and Mr. Wager has informed me that he is in doubt as to whether the nucleus of the mature oosphere of *Peronospora* is, after all, composite in origin. This strained analogy between the behaviour of the nuclei in cells and cœnocytes is further weakened by two considerations—first, in the cœnocytes it is not a question of the union of two definitely prepared nuclei; secondly, though there may be repeated nuclear fusions in the Ascomycetes (in *Sphaerotheca*), several cell-divisions may intervene between the successive acts.

The next objection which may be urged against the views here put forward is to the assumption that each ascus represents a complete individual. In addition to what has been said earlier in this paper, it may be pointed out that were we to adopt the only other explanation

concerning the nuclear union in the ascus, namely, that it represents a true sexual act, we should be driven to the same conclusion that each ascus represents a complete individual.

The occurrence of nuclear unions not involving a break in the life-history might be regarded as militating against the theory here put forward. And such nuclear unions are stated to occur; but the conditions under which they are stated to occur are such as to neither strengthen nor weaken the case. Were an ascus or a basidium to lose its power of producing spores, and to become sterilised in order to take on new functions, it might, nevertheless, in its youth exhibit nuclear fusions of a sexual or of a deuterogamic nature. Now, Mr. Massee (9), in addition to recording a number of interesting facts in reference to the origin of metuloids, cystidia, and other sterile cells of the hymenium in Ascomycetes and Basidiomycetes, states that in *Lachnea albo-spadicea* the large protective hairs borne on the ascophore are formed by the union of the terminal cells of two adjacent hyphæ, and that the two nuclei of the cells coalesce. Mr. Massee, however, is unable to accept the view that these protective hairs are sterilised asci; he says, "I think such" (protective hairs) "can not, by any amount of ingenuity, be considered as aborted spore-producing members." I confess I fail to see that there is any greater difficulty involved in the assumption that these hairs are sterilised asci than there is in assuming that sterilisation in flowers has led to the production of staminodes, perianth-segments, and pistillodes. I do not wish to imply, however, that all sterile cells in hymenia are sterilised asci or basidia; on the contrary, there is strong reason for believing that paraphyses in some of the Ascomycetes are merely vegetative hyphæ. It is quite possible that in one series of forms, in one representative a vegetative hypha is modified to perform a certain function, whilst, in another representative, a basidium or an ascus is metamorphosed to perform precisely the same function. In addition to these nuclear fusions in the Ascomycetes, there are others stated to occur in Angiosperms that involve no break in the life-history. Strasburger records and figures unions taking place between nuclei in the

endosperm of *Corydalis cava*, and Soltwedel makes similar statements with reference to other plants. In reference to these unions, it may be noted that they occur in the degenerate prothallium, and that, according to Strasburger, more than two nuclei may unite to form one. In fact, the phenomenon recalls the repeated nuclear union in the ascus of *Peziza Stevensoniana*.

In conclusion, then, according to the hypothesis here put forward, the fusion of the polar nuclei on the embryo-sac is no isolated and unique phenomenon. On the contrary, so far as we know, the process is repeated in every class of the vegetable kingdom where a small degenerate fructificative generation is universally parasitic upon the preceding generation. If this interpolated nuclear fusion is evidence of vegetative atrophy, we may be able to employ it as a means of distinguishing between antithetic and homologous alternation of generations, or in ascertaining if there is really such a phenomenon as antithetic alternation of generations among plants. For example, we might find nuclear fusions following the sexual act at an early stage in the development of the sporophyte of Coleochæte or those Bryophyta that possess the simplest sporophytes. On the other hand, should renewed investigation confirm Oltmann's results as to the absence of the double nuclear fusions in the Florideæ, we shall feel less inclined to assume that the sporophyte in the family is degenerate or homologous. On the other hand, we may find among the Ustilagineæ and Hemiasci types in which deuterogamy plays no part, because vegetative degeneration is not yet sufficiently complete.

In conclusion, it may be pointed out that the hypothesis here put forward is threefold in nature. According to it —(1) the nuclear fusions discussed are interpolations; (2) they are concerned with the alternation of generations, and take place in a small fructificative generation; (3) the small fructificative generation is degenerate, and, in some cases, originally homologous with the other generation.

If this third proposition were not true, that is, were the fructificative generation neither degenerate nor homologous with the other generation, yet the other two propositions

would hold good; but our physiological rationale would have to be reduced to a suggestion that the interpolated nuclear division permitted the development from a sexual or asexual spore of an offspring differing widely from that which the spore originally produced in more primitive types.

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SOME NOTES ON ANDROMEDA POLIFOLIA, LINN., WITH SPECIAL REFERENCE TO A NEW STATION IN THE LIDDESDALE DISTRICT OF ROXBURGHSHIRE. By SYMINGTON GRIEVE.

(Read 12th January 1899.)

Andromeda polifolia, Linn., is a plant that I have been able to obtain very little information about. It is, however, not very common in Scotland, as it is only noted in the second edition of Watson's "Topographical Botany" as being found in the following Watsonian vice-counties, viz.:—Dumfries, Kirkcudbright, Ayr, Renfrew, Lanark, and West Perth. The West Perth station is given by Watson from a specimen from a herbarium sent him by Dr. Stevenson Bushnan, but whether collected by Dr. Bushnan himself does not seem clear. The station referred to is probably Blairdrummond Moss, on the north bank of the Forth, and which is mentioned as a station for this plant by the late Dr. Buchanan White, at p. 234 of the "Scottish

Naturalist" for 1882. Mr. Arthur Bennett, F.L.S., in "Additional Records of Plants from Scotland," published in "The Scottish Naturalist" for 1886, mentions the occurrence of *A. polifolia*, Linn., in vice-county No. 74, Wigtown.

Mr. John Elliot, 2 South Liddle Street, Newcastleton, Roxburghshire, discovered *A. polifolia*, Linn., near Tinnis Hill about thirty-one years ago, but it is only about two years since that he knew its name. He has since discovered another station for the plant, and I can confirm his discoveries, as I have seen the plant at both stations. Mr. Elliot writes me on 2nd January 1899:—"Regarding my experience with *Andromeda*: Just about thirty-one years ago I was helping my two uncles to build a parish church over in Ewesdale, and going over the moors (for we left the turnpike near Tinnis Hill) I was always looking for plants. I happened to pick one up I had never seen before. I told a botanical friend, a member of the Berwickshire Naturalist Club, about this plant some three years ago. He suggested *Linnæa borealis*. I said no. I thought I would have a hunt for it again. I looked about several times, and two years ago I came across it."

The foregoing discovery of Mr. John Elliot evidently was unknown to Professor J. W. H. Traill, of Aberdeen, when he published in the "Annals of Scottish Natural History," p. 232, October 1898, a list of the vice-counties in which *A. polifolia*, Linn., is found in Scotland. He gives vice-county 86, Stirling, which is an addition to Scottish stations, but makes no mention of vice-county 80, Roxburghshire, which must be added on Mr. John Elliot's authority. I have had the pleasure of going with Mr. Elliot to one of the stations he discovered, at which it grows in great plenty over a considerable area in a wet peat bog. It is, however, a plant that has been known in the district for a very long time, as it is mentioned by Lightfoot in his "Flora Scotica," published in 1777, although the facts mentioned by him were collected in 1772, during his tour in Scotland and England with Thomas Pennant. Lightfoot says at p. 215 regarding *A. polifolia*, Linn., or *Marsh Andromeda*, or *Marsh Rosemary*, found "abundantly upon Solway Moss, on the borders of

the two kingdoms. The plant seems widely distributed in Liddesdale, and evidently may be found from sea-level up to the highest station, where I have found it about 1090 ft."

In 1896 I found it twice at stations on the opposite side of the river Liddel from those known to Mr. Elliot, and, after identifying the plant, and finding it seemed to be from the floras I had access to—a fairly common plant in the Border counties,—I thought nothing more about it, until my friend the Rev. Dr. Paul asked if I had been observing the plant, which was, he thought, of special interest. After looking into the subject a little more, I came to the conclusion that the Rev. Dr. Paul was right, and that it was worth while making some further investigations, and it is with these I am troubling you on this occasion.

It is unfortunate that I have been unable to ascertain the altitude of the Scottish stations at which the plant has been found—although Watson mentions that it has been found at 600 ft.—except, of course, where I have observed it myself, and to which I will have to refer further. However, as Solway Moss on the west side of Scotland, and Blairdrummond Moss on the east side of Scotland (Forth district), may be said to be both near sea-level, it proves the plant to grow under conditions in this country quite different from those in which it is found in some other parts of the Northern Hemisphere, and this aspect of the question requires to be mentioned.

The stations at which I have seen the plant in Liddesdale are on the following elevations: about 700, 800, 1000, and 1090 ft. above sea-level. I am informed by Mr. John Elliot it begins flowering in April, and is perhaps most easily seen towards the end of May, when it is in full flower. Most of the flowering stems project a few inches above the surface of the bog, which makes it visible among the moss and heather.

It appears to grow in patches, some of which are one or more acres in extent. I have seen it flowering at the end of May, and in October as I mention. I also found it in fruit in August.

About the middle of last June I visited the 1090 ft. station with some friends, and, although we searched

diligently over the ground where we were told it grew, only one of us found a specimen. About the middle of July I returned to this place, and examined it, and adjoining ground, but did not get even one specimen, although Mr. John Elliot assures me it was quite plentiful earlier in the season, and feels sure he could have found it, although hidden among the heather. During the fourth week in August, as one of the guests of the Berwickshire Field Club at their excursion to Liddesdale, I was taken by Mr. John Elliot, along with others, to a new station he had discovered at an elevation of about 1000 ft., and we found the *A. polifolia* growing abundantly in a very wet peat moss, such as would be described in Liddesdale as a "flow." Hearing that the plant had been introduced into some gardens at Newcastleton with success, I took some plants and had them put into a plot at my house, where the *Andromeda* seemed quite to establish itself at once. I was rather surprised to find it was flowering at the beginning of October, which was presumably the second time of flowering this year. Altogether, *A. polifolia*, Linn., appears to be a most interesting plant, as it can adapt itself to widely different conditions of climate and soil, and yet thrive.

But perhaps the most interesting circumstance connected with *A. polifolia*, Linn., is the great difference in altitude at which it is found, and its wide range. It is found on the high mountains of Central Europe and Spain, and northwards to Arctic Europe, Greenland, and the Arctic regions, also in Asia and Canada, and Western America.

In the "Flora of the Alps," Mr. A. W. Bennett says of *A. polifolia*: "Alpine bogs, Switzerland, Jura, Vosges, Tyrol, Pyrenees."

The plant has been long well known in the low country of Germany as being found in bogs, as a number of stations are given by Roth, in his "Flora of Germany," published in 1788.

Mr. Arthur Bennett, F.L.S., of Croydon, kindly informs me that there are, as far as he knows, no records of altitudes for *A. polifolia* for the west of Scandinavia, but from Arctic Norway the plant has been got from the

following altitudes :—In the Rödö district, at 6 ft., 1061 ft., 2222 ft. to 2268 ft. above sea-level; in the Lofoden district, 0 to 1036 ft.; in the Hindö district, 0 to 2441 ft.; in the Alten district, 0 to 1782 ft.; in Laksefjord district, 0 to 1444 ft.; in Jure Finmarken district, 2 to 1750 ft. From 3000 to 3500 ft. in other parts of Norway.

Greenland.—No altitude given for *A. polifolia*, Linn., but another species is mentioned as being found at an altitude of 2000 ft.

Canada.—No information as to altitude in Canadian list by Macorm.

North America.—The plant is found south of Canada, but no information as to altitude is given in "Floras."

Asia.—No information as to altitude.

In Ireland *A. polifolia*, Linn., is found up to an altitude of 1500 ft. in Dublin and Wicklow, but usually is found as a lowland plant.—"Cybelene Hibernica," 2nd ed. p. 223, 1898.

With such a wide range of distribution, one would naturally expect to find *A. polifolia*, Linn., as one of our Scottish Alpine plants. It is, however, unknown in our Highlands, and the Celtic inhabitants do not appear to have had any name for it, as Mr. John Cameron, in his Gaelic names for plants, under "Ericaceæ," at p. 23 of the "Scottish Naturalist" for January 1881, does not mention it.

It is rather remarkable that it does not appear to be found in Iceland. I have referred to a number of authorities, and they all mention an allied species, *A. hypnoides*, Linn., as being met with. For instance, in "Recollections of a Tour in Iceland in 1809," by William Jackson Hooker, F.L.S., p. 68, the author describes a ramble over the Helgafel Mountains near Reikevig, on 1st July 1809. At p. 70 he says: "The worst was, I could not have well chosen a more barren spot for plants in so long a ramble, though I met with one species that delighted me much, and made me forget the fatigue. This was *A. hypnoides*, which I found just in flower on the north side of a huge mass of lava, and only there."

In a note to the same page, Hooker says with regard to

A. hypnoides: "The delicate tint of the flowers was here finely contrasted with the uniform blackness of the lava. Its barren shoots, as is observed by Linnæus, exactly resembles those of a moss, or of a small Lycopodium."

On 12th July 1809, when on his way to the Geysers, at p. 99 the same author says: "At the mouth of one (a cave) I found a miserable specimen of *A. hypnoides*, and a few plants of *Pyrola minor.*"

Sir George Stewart-Mackenzie, Bart., in his "Travels in Iceland," published 1812, App. p. 414, gives *A. hypnoides*, on the authority of Hooker.

Professor C. C. Babington, in his paper on the "Flora of Iceland," "Journal of Linnæan Society," Botany xi. p. 316, mentions *A. hypnoides* as abundant in the eastern part of the island, and mountains above Akreyri. Grows on lava on road to the Geysers.

Dr. Lauder Lindsay, in his paper on the "Flora of Iceland," "Transactions of the Botanical Society, Edinburgh," vol. vii. p. 141 (this paper was read 11th April 1861), only mentions *A. hypnoides*, Linn.

One cannot read these notes without feeling that the conditions of soil suitable for *A. hypnoides* were quite different from those requisite for *A. polifolia*,—the former growing upon the volcanic rock, the latter in the deep, wet soil of peat bogs. In Liddesdale I found it most abundant in the wettest situations, its lateral roots, with many diverging rootlets, a few inches beneath the surface of the bog, and sometimes appearing upon its surface, with the barren stems generally more or less prostrate, and the flowering stems raised from three to six inches from the ground.

Altogether, it appears to me that *A. polifolia* is well worth our consideration. What, we may ask, are the conditions prevailing in our Highlands, and also in Iceland, preventing its growth? It cannot be any want of suitability in the climate, as we find the plant growing in the comparatively warm low country of Northern Germany, and at, or near, sea-level in Great Britain and Ireland, and yet we find it as an Alpine plant in the high mountains of Central Europe and Northern Spain, in the high mountains of Northern Scandinavia, in Greenland,

the Arctic regions of North America, and in Asia. In other words, we find it growing from regions rendered humid under the influence of the Gulf Stream, to the regions of perpetual snow and ice.

But that is not all. We find that its natural situation is peat bogs, but it has been transplanted to a dry soil in a garden border, and grown successfully without any special care for years. My own attempt in the same direction I have told you of, but surely it is some evidence that the plant is thriving when it flowers out of time after being transplanted.

It would be unsatisfactory to pronounce any definite opinions as to the causes which enable the plant to exist under such different conditions with the meagre evidence before us, but I might almost hazard the guess that it will be found that some constituents in the soil (possibly lime or peat) have more to do with the healthy growth of the plant than mere climatic conditions.

May I ask that some of you, better equipped for such investigations, will give *A. polifolia* your consideration and study, in the hope that more light may be shed upon its cultivation, life-history, and distribution ?

ON THE DEVELOPMENT OF QUADRIFOLIAR SPURS IN PINUS LARICIO, POIR. By A. W. BORTHWICK, B.Sc. (With Plate.)

(Read 12th January 1899.)

Pinus Laricio, the black pine, was introduced during the present century into Britain. It is a forest tree of no mean importance, and for ornamental purposes it is greatly prized. The stem is straight and well formed, reaching a height of sixty to seventy-five feet at maturity. The natural distribution of this species is in Southern Europe, stretching from the south of Spain to Asia Minor, and from Wiener Wald south to Sicily.

On account of the regular whorl branching, the deep corona, and thick dark green needles, this tree is well adapted for parks and ornamental grounds, especially in the vicinity of large towns, as it withstands the smoky atmosphere better than any other pine. This species has been relegated to the section Pinaster, sub-section Pinea,

but for practical purposes the pines might be divided into three sections—Pinaster, Tæda, and Cembra, according as they have two, three, or five needles on one branch of limited growth. In this classification *Pinus Laricio* might belong to the sections Pinaster or Tæda equally well, since it is a common thing to find two or three needles in one sheath on the same individual. Beissner's classification, however, obviates this difficulty, and owing to the structure of the cone, which has no strong protruding spur such as is found in the section Tæda, the black pine takes its place in section Pinaster.

Like other pines, this species occurs in several different forms, distinguished by the leaves or habit of growth, such as—(1) *Pinus Laricio Austriaca*, the black Austrian pine, whose needles are long and coarse with yellow tips; (2) *Pinus Laricio Poiretiana*, the Corsican black pine, with needles like the former, but twisted in young plants; (3) *Pinus Laricio Pallasiana*, needles long, coarse, and stiff; the periderm of young shoots is yellowish, while it is grey-brown in *Austriaca*, and light brown in *Poiretiana*; (4) *Pinus Laricio Monspeliensis*, of Southern France, has softer and more delicate needles of a lighter green, with very distinctly serrulate margins, and the periderm of young shoots is reddish yellow. In all these we may get growth forms, as—the drooping form, *Pendula*; the dwarf forms, *Pygmea*, *Monstrosa*, and *Bujoti*; and lastly, the serpent form, *Virgata*. In a young mixed plantation, consisting of larch, spruce, and pine, I found a black pine, the age of which I estimated to be twelve years. It had a diameter of three and a half inches, and a height of eleven feet. For the last two years it had produced no whorl branches, and the apex was occupied by an unusually large single bud, which was fully an inch long and half an inch broad. About three inches below this bud was a ring of undeveloped buds, five in number, alternating with four side shoots averaging about six inches in length. Farther down, about eighteen inches below the apex, was one side shoot eight inches long. This shoot was undoubtedly developed from a branch of limited growth, since the needles were still adhering to its base. The origin of the ring of buds farther up is more obscure.

The upper part of the tree, which I may call the virgata or serpent part, was densely covered with long thick needles, occurring in bi-, tri-, and quadrifoliar spurs. The bifoliar spurs of the upper part were much longer than those of the lower or normal part, the average difference being 2·2 inches. Bifoliar and trifoliar spurs occurred all over the tree, but the quadrifoliar spurs were entirely confined to the upper part. The quadrifoliar spurs were heterophyllous, the fourth needle being shorter and thinner than the other three, which averaged 6·78 inches in length, while the fourth needle averaged 4·08 inches, it is therefore 2·7 inches shorter than the other three. In addition to being the smallest, it is the highest inserted needle of the sheath. A longitudinal section shows that it belongs to the interfoliar bud, being, in fact, a metamorphosed bud scale. The other three needles were produced by the last three leaves of the branch of limited growth in the normal manner, and they are therefore arranged round the apex of the branch, with their bases nearly in the same plane; but the base of the fourth needle is much higher, its point of insertion being opposite that of the first scale leaf of the interfoliar bud, as may be seen from the photomicrograph. That the fourth leaf is a subsequent formation may be seen by a transverse section just above the leaf sheath. The three larger and first formed leaves together form a circle, their inner sides converging at angles of 60°. The regularity of this arrangement, however, is broken by the fourth leaf, which has grown up between the others, flattening their inner angles, and giving them a more or less polygonal outline. The fourth needle itself is plano-convex, but at one of its angles there is a peculiar outgrowth which has been caused by the crushing of the other leaves.

A transverse section of the three larger needles showed them to have the typical structure. The resin canals were not in contact with the hypoderm, as in the the Scots pine, but were embedded in the mesophyll, and though varying in number in different leaves, still they all showed the median upper resin canal so typical of a certain number of pines, including *Pinus Laricio*. The vascular bundle was

DESCRIPTION OF PLATE.

A quadrifoliar spur in longitudinal section. On the left is seen the base of a normal needle, on the right two needle bases, the outer and lower inserted being normal; the inner, smaller and higher inserted, being the fourth and abnormal needle of the spur. Centrally is the interfoliar bud with its scale leaves.

double, and its orientation normal. The transfusion tissue was present in the usual amount.

On examining a transverse section of the fourth needle, I found only two resin canals, right and left of the vascular bundle, embedded in the mesophyll. The transfusion tissue was not so abundant as in the other needles, and the vascular bundle was single. The xylem was towards the convex, and the phloem towards the plane side of the leaf, exactly the opposite of what is found in the normal condition. In the position and number of the resin canals, and the orientation of the vascular bundle, this leaf agrees in structure with what is found in the leaf of *Pinus Monophylla*, according to the description given by Maxwell T. Masters in the "Annals of Botany," vol. ii. p. 124.

It may be interesting to notice here that according to Bertrand—"Annales des Sciences Naturelles," series v. vol. xx.—the resin canals of the scale leaves are not continuous with those of the axis, but the photomicrograph of the longitudinal section of the branch of limited growth and interfoliar bud shows distinctly a branch passing from a resin canal at the axis into a scale leaf. I have also found scale leaves of other buds receiving branches from the resin canals of the axis.

After the third year the primary spirally-arranged green leaves of the pine appear only as dry scales, bearing branches of limited growth in their axils, and most authorities agree that when such scales become changed into green leaves, they are short and flat, in fact, they become the typical rosette-shoot leaves; but the fourth needle, which has the same origin as the rosette-shoot leaves, is thin and needle-like, and although it shows some of the primary leaf characters internally, still, in outward appearance, it resembles the normal acicular leaves, exhibiting, in fact, a transition stage between the two.

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On Interfoliar Buds in Pines.

By A. W. Borthwick, B.Sc.

(Read 12th January 1899.)

The bud which represents the future shoot is found in very various stages of development, according to the species of plant to which it belongs. In many cases it consists merely of a papilla of cells, and will develop only under certain conditions. The winter buds of our trees and shrubs are more or less highly developed, but it is among the conifers that we find the two extremes. The one extreme—the highest development—is found in the end and whorl buds of pines. There all the leaves are metamorphosed into dry scales, and their axillary buds are so highly differentiated that the foliar spurs may be recognised. The other extreme—the lowest development—is seen in the winter buds of *Abies* and *Picea*, where the future shoot is represented merely by a green, fleshy tubercle, bearing on its surface small papillæ, which are the leaf rudiments. In order to protect this bud, the apex of last year's shoot is swollen out, and the needles belonging to it are changed to scales, which cover the real bud like a cap.

The pine tree possesses the following kinds of buds:—(1) apical buds; (2) whorl buds—(*a*) such as produce whorl branches, (*b*) such as produce female flowers, (*c*) dormant buds, or cryptoblasts, which develop after severe damage to the leaves, etc.; (3) interfoliar buds, or brachyoblasts; (4) axillary buds in the axils of primary leaves in the young plant (such buds become functionless after the fifth year, when bark formation begins); lastly, primary leaf axil-buds on young shoots, which produce male flowers.

The apical and whorl buds, or macroblasts, I have already briefly described, and will now pass on to consider the occurrence, structure, and function of dormant buds or cryptoblasts.

Regularly one or two of the whorl buds remain dormant, that is, do not shoot out the year after their formation. Some authorities hold that dormant buds occur only on very old trees, and will develop only after the tree has

been badly damaged by insects. In these quiescent buds, the primary leaves having been only partially changed to scales, the so-called rosette shoot results. On the other hand, according to Hempel and Wilhelm, the cryptoblasts of *Pinus Laricio* often develop after a year or two into normal branches of unlimited growth, which are covered with scale leaves, in whose axils foliar spurs are produced, and this happens with apparently no cause.

My observations go to confirm the statements of these latter investigators, that the dormant buds can produce more than mere rosette shoots. I have frequently found between the old branches of a whorl young shoots only a few millimetres in length, on which bifoliar spurs were appearing. On a young Scots pine I found a ring of some very young shoots developing between the branches of a whorl which was four years old. That these young shoots were not developed from interfoliar buds was evident for two reasons—first, they showed no subtending leaf-scars; second, the main axis had lost all its bifoliar spurs for a considerable distance above this whorl. At present I have numerous experiments in course of progress, by which I hope to obtain evidence confirmatory of the opinion I have just expressed as to the origin of these extra shoots.

Hartig states that the conditions under which such buds develop are very various; but they have this in common, that an increased supply of nutriment reaches the buds, and this may be caused, for example, by pruning, light thinning, defoliation by insects, or late frosts. All these factors are at work in the plantation where I made my observations. It is true, the late frosts were not very intense, and the defoliation was only partial, but to compensate, the thinning and pruning were very severe.

Very similar to the dormant are the interfoliar buds which occur between the needles at the apex of the branch of limited growth. The first leaves of the branch of limited growth form the needle sheath, the last leaves the needles themselves, between which is found the interfoliar bud, which generally undergoes no further development.

The duration of the bifoliar spur varies from one and a half to twenty years, according to the age of the tree and

the climate. In order that it may not be grown over by the thickening stem, the cells of the branch remain merismatic where it passes through the cambium of the mother axis, and increase in length takes place inwardly equal to the breadth of the wood ring, and outwardly equal to that of the bast.

The branch of limited growth thus elongates in a manner similar to that of a medullary ray. The interfoliar bud develops only under the stimulus of an increased supply of nutriment. This may occur—(1) if the phloem of the shoot is damaged, and the elaborated sap consequently cannot pass down beyond the seat of injury; (2) if the side branches are suppressed; and lastly, if the end and whorl buds of the shoot are destroyed.

In the plantation to which I have already referred, the pine shoot beetle (*Hylesinus piniperda*) is very common. The thinnings and other cut material were allowed to lie in the wood, thus forming the best breeding place possible for the beetle, which consequently appeared in great numbers last spring. The adult beetle hibernates in the cut material, and flight occurs in spring. The adult attacks the young shoots, boring into them and tunnelling out the pith towards the apex. The shoot is killed, becomes dry, and is snapped off by the wind at the spot where the insect began its operations. At a distance, the tree looks as if it had been clipped with scissors, hence the Germans call this insect the Waldgärtner, or forest gardener. Nearly every tree in the plantation lost a great many buds in this manner. In most cases where the leader had been destroyed, the developing interfoliar buds gave the appearance of miniature witches' brooms on the tree. This curious effect was produced by their thick bushy growth and by the character of the needles, which were short, thick, and fleshy, and much lighter in colour than the rest. A transverse section of those short thick needles showed them to have an abnormal number of resin canals, as many as eighteen or twenty occurring in one leaf. A case is cited by Schacht—"Lehrbuch d. Anatomie u. Physiologie," p. 121—where as many as twenty-four were found. This great number he attributes to the very luxuriant growth of the tree. A longitudinal

section of one of those buds showed a structure agreeing in every respect with the apical or whorl buds, except that the bud is joined to the branch of limited growth by a narrow neck, which gives a peculiar constricted appearance to its base. A section of the undeveloped interfoliar bud in the normal condition shows simply a papilla of cells occupying the apex of the shoot between the bases of the two needles. Its primary leaves are not changed to scales, nor does it develop under ordinary conditions. We have evidently a bud here agreeing very closely in structure and function with the dormant whorl bud, and might reasonably expect it to produce the same results. But authorities differ very widely on this point, some say that interfoliar buds produce branches of unlimited growth, and that dormant buds produce only rosette shoots, while others say that both can produce branches of unlimited growth.

My observations tend to show that both cryptoblasts and brachyoblasts can produce either kind of branch, the results varying with the conditions under which the buds are induced to develop and the general health of the tree at the time. We have seen that complete defoliation by insects can cause dormant buds to develop, also that an accession of nutriment may have the same effect; but in the former case a rosette shoot results in, in the latter, a branch of unlimited growth. The reason for this is not far to seek. In the first case, the vitality of the tree has received a severe check, and there is neither time nor energy left for the formation of bifoliar spurs in the axils of the primary leaves, so we get a rosette shoot. In the second case, the conditions are more favourable, and buds are formed in the primary leaf axils, with the result that we get branches of unlimited growth. This holds good for the brachyoblasts also. That the health and vigour of the tree affects the formation of axillary buds is shown even in the seedling. At the end of the first year weak plants form only an apical bud, stronger plants form, in addition to this, buds in the axils of their primary leaves, which in even stronger plants may develop. If at this early stage the bifoliar-spur needles are destroyed by insects, the brachyoblast develops into a shoot covered with primary

leaves, which, only if the plant is strong, produce bifoliar spurs in their axils. We thus see that brachyoblasts and cryptoblasts produce either rosette shoots or branches of unlimited growth according to the conditions which induce their development. A knowledge of these conditions is not only of interest to the botanist, but is of practical importance to the forester and gardener. In order to make my meaning more apparent, let me quote Dr. Masters. On page 7 of "The Report on the Conifer Conference," he says: "I may also call your attention to the way in which some of the shoots of some species of pines are clothed to the base with leaves, whilst in others the base of the shoot is bare. The scraggy unfurnished appearance of some old pines is accounted for by this peculiarity. What to suggest as a remedy in this case is not so easy; nevertheless the frequent appearance of numerous adventitious shoots on the trunks of such species as *Pinus rigida* and *Sabiniana* or *Sequoia sempervirens* seems to show that, by a judicious disbudding or removal of the tips of some of the upper shoots forming the head, a more bushy, or, as gardeners call it, a more furnished, habit would result." I willingly agree with Dr. Masters, that by a careful and judicious disbudding the appearance of a scraggy pine tree might be vastly improved, and if all pines are not so fortunate as *Pinus rigida* and *Sabiniana* in possessing adventitious shoots, still they all have interfoliar buds which, given the proper conditions, would produce the same results; and I hope to be able to throw fresh light on the matter when the results of my experiments, now in progress, are to hand.

The work of this, and the preceding paper, was done in the Botanical Laboratory, St. Andrews, and I have to express my appreciation of the facilities afforded me there. I am specially indebted to the lecturer, Mr. Robertson, for the photomicrograph.

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NOTES ON MICRO-METHODS. By ALEX. LUNDIE, Botanical Department, The University, St. Andrews.

(Communicated 12th January 1899.)

1. METHOD OF MOUNTING FUNGI IN GLYCERINE.

The difficulties usually encountered in mounting fungi, like Eurotium, etc., are the expulsion of air from the preparations, and the proper teasing out of the filaments.

When the conidiaphores are ripe, and conidia are being shed, it is impossible to wet the fungus completely with water. Absolute alcohol, however, wets it, but chloroform, which has less surface tension, wets it more easily, and penetrates all through the mycelium, leaving little air entangled even in the sterigmata.

If a piece of Eurotium be placed on a slide, wetted with chloroform, strong glycerine added, and covered with a coverslip and heated over a Bunsen flame, the chloroform boils off rapidly and drives out the last traces of air. The bubbles of chloroform vapour, in passing out, scatter the hyphæ and tease out the preparation, without breaking it up, as is done when needles are used for mechanical teasing.

2. PHOTO-CHEMICAL METHODS OF STAINING MUCILAGINOUS PLANTS.

Staining by Chromatype Method.—A saturated solution of potassium dichromate, mixed with one-twentieth of its volume of saturated cobalt nitrate solution, is used. In the original method for photographic work, nickel sulphate was recommended—not cobalt nitrate. It was said to make the prepared paper more sensitive to light.

A piece of an alga, *Batrachospermum*, for example, is suspended in this mixture in a glass tube, and exposed to diffuse daylight for thirty minutes. It is then transferred to a slide, and treated with silver nitrate solution, and again exposed to light for five minutes. The nitrate is now removed, and ammonium chloride solution is added and allowed to remain until all the chromate has become

converted to chloride. The completion of this reaction is marked by the disappearance of the characteristic red coloration of silver chromate. The surplus liquid is now dried off by cigarette paper, and the excess of silver chloride removed by sodium thiosulphate solution. After thorough washing, the preparation is either mounted in glycerine, or, after dehydration by absolute alcohol, in Canada balsam.

The staining is uniform throughout, and not merely superficial. The colour is yellow, and the outline of the mucilage is quite sharply marked off.

In the chromatype process of photography, paper is sensitised by treatment with a saturated solution of potassium dichromate, mixed with either copper or nickel sulphate. When dry, the paper is exposed in a camera. A dark brown negative is thus obtained. It is now washed over with solution of silver nitrate, and developed in sunlight. Short development gives a negative, but further development gives a positive. On being washed over with sodium chloride solution, the image fades away entirely, but reappears as a pale violet-coloured positive on exposure to sunlight.

The idea of applying this method to botanical microscopic work was suggested by the fact that gelatine combines with potassium dichromate in daylight, and with it forms an insoluble compound. It appears that the mucilage of such plants as *Batrachospermum*, *Rivularia*, etc., can be impregnated with dichromate also; and when this is done, it is then possible to impart a definite colour to the mucilage by following out the chromatype method.

Even if the dichromate did not combine with the mucilage, the subsequent treatment with silver nitrate and alkali chlorides would fix the colouring matter, and prevent it being washed out. It has not been ascertained how much dichromate is reduced by the action of light and combined with the mucilage. It is possible to wash out the most of it with water, but this should not be done in practice if a deep coloration is required.

Attempts to stain mucilage by steeping in potassium iodide solution, sensitising with silver nitrate, exposing, and developing, have not been particularly successful.

The sensitive salt was deposited only on the surface of the mucilage, and not in the interior at all. This method, however, gives better results with flax seeds, but here the same difficulty of impregnating the mucilage with a sensitive silver salt again presents itself. Potassium dichromate readily saturates mucilaginous membranes and mucilage, perhaps in virtue of its property of combining with them on exposure to light. It is hardly possible to impregnate the mucilage of fresh-water plants with either potassium iodide or silver nitrate, without thereby causing the mucilage to shrink up and almost disappear.

The application of this process to seaweeds is interesting, as it apparently indicates a method of determining the distribution and the chemical nature of salts present in the tissues of these plants.

The medulla of the thallus of *Fucus* consists of cells apparently embedded in a transparent gelatinous matrix. Treatment with Schulzé's fluid shows that the cell membranes consist of two strata—an inner dense layer immediately around the cell contents, which gives a blue reaction with Schulzé's fluid; and an outer gelatinous layer, which forms the apparently gelatinous matrix, and which is unacted upon by the above treatment.

When sections of *Fucus* are swelled out for a short time in fresh water, and then treated with weak silver nitrate solution, certain unstable silver salts are formed, and impart a white coloration to the sections. They now behave like sensitised gelatine plates, being, in fact, specially sensitive, and may be developed by the usual methods. Before developing, they should be brushed over in fresh water with a camels' hair brush, to remove any silver salt precipitated superficially. They may now be transferred to a slide, developed with hydroquinone, and fixed with sodium thiosulphate. An exposure of three minutes in gaslight is quite enough to give a very deep coloration on subsequent development. The gelatinous matrix stains of a uniform yellowish brown, the cellulosic layer does not stain at all, and there appears between it and the gelatinous matrix a thin darkly-coloured ring. The cell contents are blackened, and the appearance of the finished preparation is rather remarkable. The dark ring

between the mucilage and the cellulosic wall may be due to a great concentration of sensitive salt in that region, or it may be due to the presence of some specially sensitive salt not existing in other parts of the plant. The fact that gaslight is enough to cause reduction of the silver salt, points to this latter theory as being the more probable. It also suggests the likelihood of halogens being held in rather complex molecules in the tissues, in addition to their existence therein, as simple salts derived from the sea, and not yet further elaborated by the metabolic processes due to the plant's activity.

On Contact Negatives for the Comparative Study of Woods. By R. A. Robertson, M.A., B.Sc. (With Plate.)

(Read 12th January 1899.)

The object aimed at was to devise a method by which several large sections of woods might be obtained on a single sensitive plate, which could be used either as a lantern slide directly, or as a negative for giving, by exposure, ordinary prints. The following conditions had to be fulfilled:—the sections must be large enough to show the diagnostic characters of the wood; the magnification, if any, must be uniform; and there must be enough detail so as to permit of projection or examination directly with a two-inch objective. The difficulties to be overcome are fairly obvious to all workers in photography.

It may be well to recapitulate here some of the various ways by which an image, capable of development as a sensitive plate, may be obtained—

(*a*) The photo-chemical process, in which the plate is exposed to light, and the chemical processes thus started are carried on by further treatment with certain chemical substances.—Unique preparations of the retina in the shape of contact negative prints on paper by an application of this process are described by Musgrove, in "Proc. Scot. Mic. Soc.," 1891–92.

(*b*) The mechanical pressure method.—By sufficient mechanical pressure an invisible image can be produced on the sensitive plate capable of development in the ordinary

way. This has been shown to be possible for iodised and bromised collodion plates, and also for gelatine emulsion plates, by Carey Lea, Eder, Warnerke, Abney, and others.

The origin of the image in this case is difficult of explanation. Meldola ("Chemistry of Photography") suggests that as it has been proved possible to produce minute chemical changes in compounds by mechanical pressure, so it is "not improbable that the silver haloids in presence of sensitisers should undergo a minute amount of decomposition by strong mechanical pressure, the decomposition being so infinitesimal as to be revealed only on application by that most sensitive of micro-chemical tests—the photographic developer."

(*c*) The purely chemical method.—By alkaline solutions of glucose and lactose, as well as alkaline hypophosphites, a developable image may be obtained on the sensitive plate.

By these methods, negatives may be obtained.

(*d*) Direct positives can be prepared by solarisation.—In 1859, Poitevin showed that it was possible to obtain direct positives on glass, instead of negatives, by using potassium iodide as an artificial solarising agent. An iodised collodion plate is sensitised and exposed to diffuse daylight for a few seconds, a film of "reduction product" (Meldola) is formed on the surface of the unaltered haloid. After washing to remove the silver nitrate, the plate is coated with a film of potassium iodide, and a long exposure is given.

"The most strongly illuminated portion of the film becomes rehalogenised, while the deep shadows remain as unaltered reduction product, and the intermediate shades get partially rehalogenised. On development, the high lights therefore come out white, the shadows dark, and the intermediate shades of an intermediate tint; in other words, we get a positive instead of a negative."—(Meldola, "Chemistry of Photography.")

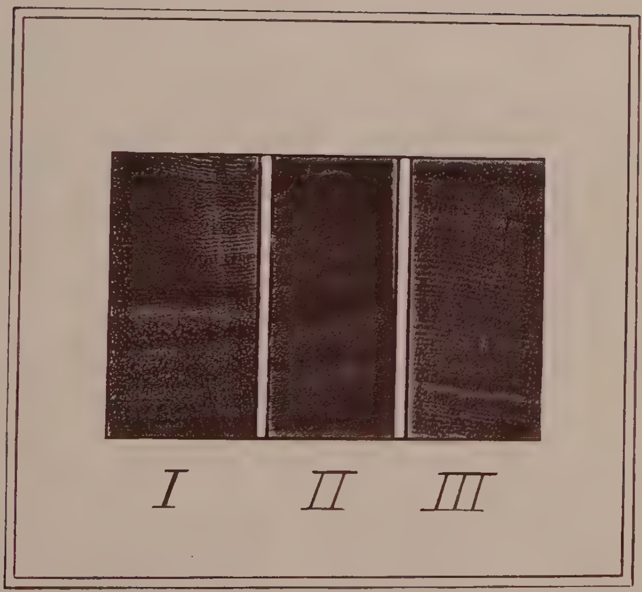
Of these four methods, I propose to give in the present paper a résumé of my experiments and results in the first two — the mechanical and photo-chemical. From the former method, I have as yet obtained no results. Whether my plates were not sensitive enough, or whether the pressure applied was not sufficient, I cannot say, but, at all

events, I was unable to get the developable image. Further experiments are in progress with this method.

The photo-chemical process gave, for the work in hand, quite satisfactory results, and my method of using it is as follows:—

Preparation of the Sections.—The material from which the sections were cut was in most cases typical blocks of wood, which had been seasoned ten, fifteen, or more years ago, and which had been used as museum specimens. From these, hand-plane sections were prepared, as large and as thin as possible. Naturally, these sections were extremely brittle, and betrayed a tendency to curl up, which rendered manipulation difficult. The largest of these, in some cases six inches long and two to three inches broad, were immersed for twenty-four hours or more, according to the character of the wood, in a flat dish containing a mixture of absolute alcohol and glycerine, about half and half, and kept flattened by a glass plate. This treatment got rid of the air, flattened the sections, and removed the brittleness to a workable extent. Thence they were transferred to the staining fluid. In the choice of this last, one had to be guided by various considerations, more especially a stain had to be selected that would give good contrasts and differentiation, not merely in the actual section, but which would show as such on the developed plate. A series of experiments made on these lines with various stains, alcohol or water soluble, proved that, of all, Bismarck Brown or Orange G. in saturated watery solutions gave the best results. After prolonged staining, the sections were toned with spirit, dehydrated with absolute alcohol, and left in oil of cloves for a day or two if intended ultimately for mounting in balsam. If to be mounted in glycerine-jelly, the sections were transferred from absolute alcohol to absolute and glycerine, half and half, and then into pure glycerine.

Printing.—The sections thus cleared are used as negatives, so to speak, for direct contact printing with lantern plates. A plate of glass is fitted into the ordinary printing frame, and on this the series of wood sections is arranged, in a thin layer of oil of cloves, or of glycerine, as the case may be. In the dark room an ordinary lantern-



EXPLANATION OF PLATE

Three Contact Photographs on one Plate of Micro-Sections of Bauhinias—I. *B. Variegata*; II. *B. Racemosa*; III. *B. Malabarica.*

slide is placed in contact with these, and clamped down very firmly, so as to ensure the expulsion of all air-bells and to have the surfaces uniformly in contact. The plate was exposed to the light of an ordinary gas-burner; the time of exposure was varied, so as to ascertain what gave best results—a long exposure to a weak light, or a short exposure to a strong light. After exposing, the plate was washed—in the case of clove-oil preparations, in alcohol, followed by water; in the case of glycerine preparations, in water merely. The plates, which were Ilford, were developed with hydroquinone, and experiments showed that, if anything, better results in the way of finer detail were got with a weak or used developer than with a developer of full strength. The interesting researches of Forgan, in "Proc. Brit. Astron. Assoc.," and Carlier, in "Proc. of Scot. Mic. Soc.," 1896–97, were very suggestive in this connection.

The general results varied—the variation depending on the ordinary factors, as exposure and developer, and on the additional ones of thinness and staining. The necessity of cutting sections of large size from the material described, prevented the minimum of thinness being obtained, and therefore precluded the best results being made of the method.

In other work, where serial sections smaller in area, and therefore capable of being cut thinner, serve the purpose, much better results are possible. As it is, the advantages may be summarised as follows:—Serial sections can be obtained on one slide,—being contact preparations, they are all of the natural size; the plate can be used as a lantern slide directly, or as a negative to give paper prints,—for comparative work, such as described above, it gives enough detail; it stands examination and projection under an ordinary two-inch objective, the thickest sections giving at least the medullary rays, annual rings, pores of the wood, and part of the intervening tissues, the thinner ones showing the intermediate tissue more or less distinctly, and capable of standing examination, in some cases, with a one-inch objective. Beyond this magnification, the difficulty becomes technical, and concerns the emulsion itself and the grain of the plate.

FIRST RECORD OF PLANTS FROM HOPE ISLAND, BARENTZ SEA. Collected by W. S. BRUCE, F.R.S.G.S. Communicated by R. TURNBULL, B.Sc.

(Read 9th February 1899.)

Mr. Bruce's first experience of Polar work was on board the "Balaena," which visited the Antarctic seas on a sealing expedition in 1892–93. He afterwards acted as zoologist to the Jackson-Harmsworth Polar Expedition to Franz-Josef Land in 1896–97; went as naturalist on board Mr. Coats's yacht, "Blencathra," during the summer of 1898, to Kolguev Island, Novaya Zemlya and Spitzbergen; and at the end of that voyage was invited by the Prince of Monaco to accompany him in his steel yacht, "Princesse Alice," on her voyage to Spitzbergen and the Greenland Sea.

During the voyage of the "Princesse Alice," Hope Island, Bear Island, and Spitzbergen were visited. Mr. Bruce was chiefly occupied in dredging, tow-netting, and collecting of animals generally. Plant-collecting formed only a subsidiary part of his work, and this, together with the limited time spent on Hope Island, accounts for the smallness of the collection of plants from that island, which is marked on the Admiralty charts as "quite barren"; but Mr. Bruce has proved that there is a certain amount of vegetation, and his collection is the first recorded from Hope Island.

The island lies in the Barentz Sea, to the S.E. of Spitzbergen, between Franz-Josef Land and Bear Island. It lies from N.N.E. to S.S.W., is about thirteen miles long and one mile broad, and reaches a height of 1000 feet. The summit is flat, bare, and cut into gullies, in some of which lie miniature glaciers.

The vegetation of the part of the island visited was scanty, and even the lichens—luxuriant elsewhere in the Arctic—were dwarfed. On first approaching the land at the S.E. point, Mr. Bruce saw, at a distance of from a quarter to half a mile, a portion of flat land which seemed to be as green as a meadow, but, unfortunately, there was

no time to visit this comparatively rich field. Similar verdant patches, brilliant with the flowers of poppies, saxifrages, etc., are characteristic of many raised beaches in Franz-Josef Land, Spitzbergen, and other lands in the Arctic.

From the summit of the island were obtained the Red-Snow Alga (*Sphærella nivalis*), a Merismopedium (one of the Schizophyceæ), Desmids (of the Cosmarium and Calocylindrus types), various Diatoms, and a Zygnema (one of the Conjugatæ).

From the rocks and soil, generally, were gathered five lichens, several mosses, and eight flowering plants. The lichens were *Cetraria islandica*, L. (Iceland Moss); *Platysma nivale*, L.; *Stereocaulon paschale*, Ach.; *Sphærophoron coralloides*, Pers.; and *Solorina crocea*, L. The mosses probably belong to the genera Bryum, Hypnum, and Bartramia, but as none were in capsule, their species have not been determined.

The flowering plants were *Papaver nudicaule*, L. (Iceland Poppy), in a very densely-tufted form, clothed with dark brown hairs; *Stellaria humifusa*, Rottb., which usually grows close to the shore; *Saxifraga oppositifolia*, L., in smaller tufts than usual in other parts of the Arctic; *S. cernua*, L.; *S. cæspitosa*, L., var. *decipiens*, Ehrh.; *S. hieracifolia*, W. et K.; *S. Hirculus*, L.; and a grass, *Phippsia algida*, R. Br.

All were in flower, except *Stellaria humifusa*, *Saxifraga hieracifolia*, and *S. Hirculus*. All the plants in the collection are well known in other parts of the Arctic regions.

I am indebted to Colonel H. W. Feilden, who examined and named the flowering plants for me. Speaking of *Saxifraga oppositifolia*, Colonel Feilden says: "It shares with three other plants, viz. *Papaver nudicaule*, *Cerastium alpinum*, and *Dryas octopetala*, var. *integrifolia*, the position of growing in the most northern land yet reached by man, having been obtained at Lockwood Island, 83° 24′ N., by Lieutenant Lockwood, of the Greely Expedition."[1]

[1] "The Flowering Plants of Novaya Zemlya," etc., by Colonel H. W. Feilden, in the "Journal of Botany," October to December 1898. London: West, Newman, & Co.

Future explorers of Hope Island will find other plants, especially at the S.E. point mentioned by Mr. Bruce, and among them they may expect to see *Cerastium alpinum*, *Dryas octopetala*, and *Ranunculus nivalis*.

I have to thank Mr. Bruce for placing in my hands all the plants which he collected at Vardö, Kolguev, Novaya Zemlya, Franz-Josef Land, Spitzbergen, Amsterdam Island, Hope Island, and Bear Island.

In conclusion, I have been particularly struck with the prevailing characters of Arctic plants, as shown in Mr. Bruce's collections; the plants are all dwarfed, most have assumed a tufted habit of growth, while many are still more protected by a dense covering of hairs, all of which characters may be directly traceable to the peculiar conditions under which the plants live: it is the phenomenon of adaptation to the environment.

On The Ferns, Mosses, and Lichens of Rerrick. By Rev. G. M'Conachie. Communicated by the President.

(Read 9th February 1899.)

The Parish of Rerrick is truly a land of hills and howes. There is not in it, I believe, a moderately level cultivated field. The up and down nature of the ground is favourable to the growth of different kinds of plants.

In the north-east corner there is the granite hill, the broad-based Bengairn (1200 ft.). To the west of it, and divided from it by the Burn of Collin, is the Suie ridge (700–900 ft.), where the rock is greywacke. These are clad with heather. The others are covered with grass. They are—the Newlaw ridge (about 600 ft.), running west from Dundrennan to the borders of Kirkcudbright parish; the Well Hill on the seashore, with bold sandstone cliffs; to the east of it (three miles) are the Barloco Heights (475 ft.), and still farther eastward is Airds Point (200 ft.).

The principal stream is the Abbey Burn. It rises on the Suie, and after a somewhat circuitous course at first, flows from Dundrennan in a straight course southwards to

the sea, through Netherlaw Glen. The chief tributary, the overflow of the Fell Loch, at the foot of the Suie, flows through Balmangan Glen, about half a mile north of the village. The plants (I use the word as including mosses and lichens) which I shall mention have almost all been gathered within a radius of four miles from Dundrennan, and chiefly on the Suie, and in the glens of Balmangan, Netherlaw, and Barloco.

The Galloway fence, a stone dyke with hedge thorns planted in it, and overgrowing it, has been a great protection for ferns and mosses.

For Ferns, I have used Hooker and Arnott's "British Flora," 8th edition; for Mosses, Stark's "History of British Mosses," and Hobkirk's "Synopsis"; for Lichens, Lindsay's "Popular History of British Lichens," and Leighton's "Lichen Flora of Great Britain," but Dr. Stirton has named the most of the lichens for me, and Mr. M'Andrew, New Galloway, helped me with the mosses.

Beginning with DUNDRENNAN ABBEY and the GLEBE, we have of—

FERNS.—*Asplenium Trichomanes*, L., the common Spleenwort. It grows in great abundance, and I have measured fronds of it ten inches in length. Wall Rue, *A. Ruta-muraria*, L., is to be found on the boundary wall of the ruins, and on the garden walls in a few favoured spots. The other ferns are the common Polypody, *Polypodium vulgare*, L.; the Male fern of *Aspidium Filix-mas*, Sw., and two varieties of the Shield fern, *A. dilatatum*, Sw., and *A. spinulosum*, Willd.

MOSSES.—We find that beautiful moss, so common everywhere, even in shop windows, *Hypnum proliferum*, L., or *H. tamariscinum*, Hedw.; also *H. rutabulum*, L.; *H. prælongum*, Dill.; *H. tenellum*, Dicks.; *H. trichomanoides*, Schreb.; *H. plumosum*, Swartz; *H. cupressiforme*, L.; *H. squarrosum*, L.; *H. purum*, L.; *Leskia sericea*, Dill.; *Tortula muralis*, L.; *T. unguiculata*, Dill.; *T. ruralis*, L.; *Bryum capillare*, Hedw.; *B. argenteum*, L.; *Mnium affine*, Bland.; *M. undulatum*, Hedw. ("pulchræ gentis pulcherrima"); *Grimmia pulvinata*, Dill.; *Fissidens adian-*

toides, Hedw.; *F. taxifolia*, L.; *Isothecium myurum*, Poll., and in Pennygill Burn near the Glebe, *Hookeria lucens*, Sw.

LICHENS.—In the "Old Statistical Account of Scotland," it is said that "Dundrennan Abbey is almost entirely covered with a pale grey-coloured moss, which gives a character of airy lightness to the lofty columns and Gothic arches,"—a statement which has been copied into almost all the published descriptions of the Abbey. The moss in question is what is known as *Lecidea canescens*, Ach. I am not sure if Dr. Stirton has found another name for it. He wished to do so when I sent him specimens in fruit. It grows in great patches on the walls, spreading from *soredia*, and, when old, resembles a *Physcia* more than a *Lecidea*. Besides this lichen there are—*Lecanora aurantiaca*, var. *inalpina*, Ach.; *L. subfusca*, L.; *L. subfusca*, var. *gangaloides*, Ach.; *L. parella*, L.; *L. parella*, var. *pallescens*, L.; *L. ventosa*, L.; *L. umbrina*, Ach.; *L. atra*, Huds.; *L. galactina*, Ach.; and *L. tartarea*, L.; *Lecidea speirea*, Ach.; *L. alboatra*, var. *epipolia*, Ach.; *L. enteroleuca*, Ach.; *Opegrapha saxicola*, Ach.; *Parmelia saxatilis*, L.; *P. perlata*, L.; *P. Olivacea*, L., and var. *prolixa*, Ach.; *P. caperata*, L.; *Physcia parietina*, L.; *P. speciosa*, Wulf.; *Pertusaria communis*, DC.; *Peltigera canina*, Hffm.; *P. horizontalis*, Hffm.; *Sticta fuliginosa*, Dicks.

NEWLAW LOCH and HILL.

Passing along the village we turn to the left at the church into a little glen, and pass westward along the road on the south side of the hill as far as the loch, and then turn northward over the ridge. We note, in passing, that, to the non-botanical eye, there seems to be two kinds of the Male fern—the common one with green rachis, and another with the rachis slightly coloured, and densely covered towards the root with yellowish chaffy scales. The Lady fern, *Asplenium Filix-fœmina*, Bernh., shows also two kinds—one which is locally called the "Black Lady." In it the rachis is brown throughout, and it is altogether a stronger plant. The Moonwort, *Botrychium Lunaria*, Sw., grows in abundance on the north side of Newlaw Hill, and also the common Brake, *Pteris aquilina*, L. (I have found the Moonwort in various places in the parish. I have not

found the Adder's Tongue here, but I have seen it near Kirkcudbright.)

Mosses.—Of mosses, we note in addition to what we found near the Abbey, *Dicranum scoparium*, L.; *D. majus*, Turn.; *Hypnum cuspidatum*, L.; *H. purum*, Dill.; *H. stramineum*, Dicks.; *Leucobryum glaucum*, Hampe., in dense tussocks; *Funaria hygrometrica*, Hedw., where whins have been burnt; and *Didymodon purpureus*, Hook and Taylor.

Lichens.—*Lecanora glaucoma*, Hffm.; *L. sarcopis*, Whlnb.; *Lecidea geographica*, L.; *L. concentrica*, Dav.; *L. petræa*, Wulf.; *L. contigua*, Fr.; *L. lucida*, Ach.; *Cladonia pyxidata*, Fr.; *Platysma sæpincola*, Ehrh.; *Graphis scripta*, Ach., var. *pulverulenta*, Ach.; *G. elegans*, Sm., and a good few more of this difficult-to-make-out class.

Balmangan Glen.

About half a mile to the north of Dundrennan the Abbey Burns receives the tributary which, rising in the Fell Loch, flows through little Glen of Balmangan. In this glen we find of ferns—*Aspidium lobatum*, Sw.; *Asplenium Adiantum-nigrum*, L.; *Polypodium Phegopteris*, and *P. Dryopteris*.

Mosses.—*Grimmia pulvinata*, Dill.; *G. apocarpa*, var. *rivularis*, B. and S.; *Ptychomitrium polyphyllum*, Dicks.; *Fontinalis antipyretica*, L.; *Antitrichia curtipendula*, L.; *Neckera crispa*, L.; *N. complanata*, L.; *Pterogonium gracile*, Dill.; *Hypnum alopecurum*, L.; *H. plumosum*, Swartz; *H. striatum*, Schreb.; *H. piliferum*, Schreb.; *H. rusciforme*, Weis; *H. denticulatum*, L.; *H. molluscum*, Hedw.; *H. brevirostre*, Ehrh.; *H. loreum*, L.; *H. triquetrum*, L.; *H. dendroides*, Brid.

Lichens.—*Alectoria jubata*, Ach.; *Usnea barbata*, Fr.; *U. hirta*, Fr.; *Evernia prunastri*, L.; *Ramalina cuspidata*, Ach.; *R. fastigiata*, Fr.; *Physcia stellaris*, L.; and *Lecidea lithophila*, Ach.

From Balmangan Glen to Suie Hills we follow the small stream to its source in the Fell Loch, then ascend the hill.

Ferns.—The Hard fern *Blechnum boreale*, Sw.; the mountain Shield fern, *Aspidium Oreopteris*, Sw., and the

Parsley fern, *Cryptogramme crispa*, Br., on the hill-top. Eastward about three miles, in Troudale Burn, is found *Hymenophyllum Wilsoni*, Hook., and a little farther off, but more to the south, the *Ceterach officinarum*, Willd. It grows on Old Orcharton Tower.

MOSSES.—*Andreæa Rothii*, W. and M.; *Rhabdoweissia fugax*, Hedw.; *Weissia cirrhata*, Hedw.; *Campylopus atrovirens*, De Not; *C. longipilus*, B. and S.; *Dicranella heteromalla*, Hedw.; *Blindia acuta*, Hedw.; *Tortula tortuosa*, L.; *Grimmia Doniana*, Sm.; *Racomitrium aciculare*, L.; *R. sudeticum*, Funk.; *R. fasciculare*, Schrad.; *R. lanuginosum*, Hedw.; *R. canescens*, Hedw.; *Zygodon viridissimus*, Dicks.; *Tetraplodon mnioides*, L. fils. Hedw.; *Bartramia fontana*, L.; *B. arcuata*, Dicks.; *Bryum alpinum*, L.; *B. nutans*, Schreb.; *Polytrichum commune*, L.; *P. strictum*, Banks; *Sphagnum acutifolium*, Ehrh.; *S. cymbifolium*, Ehrh.; *S. squarrosum*, W. and M.; *Bryum palustre*, L.; *Hypnum scorpioides*, L.

LICHENS.—*Cetraria aculeata*, Fr.; *Cladonia alcicornis*, Flk.; *C. furcata*, Hffm.; *C. gracilis*, Hffm.; *C. rangiferina*, Hffm.; *Lecanora badia*, Ach.; *L. squamulosa*, var. *smaragdula*, Whlnb.; *Lecidea fuscoatra*, var. *fumosa*, Ach.; *L. Œderi*, Ach.; *L. Mougeottii*, Schær.; *Sphærophoron compressum*, Ach.; *S. coralloides*, Pers.; *Squamaria saxicŏla*, Poll.; *Stereocaulon paschale*, Ach.; *S. denudatum*, Flk.

The ABBEY BURN, from DUNDRENNAN, through NETHERLAW GLEN to BURNFOOT and the SEASHORE.

FERNS.—The "Basket Fern," a local name for *Aspidium angulare*, Willd., grows luxuriantly in Netherlaw Glen, and the Hart's Tongue, *Scolopendrium vulgare*, Sm., the common one, and also a crested variety. The Sea Spleenwort, *Asplenium marinum*, L., is found all along the shore, but is disappearing. I think I have mentioned all the ferns known to me which I have seen growing wild in the parish, except the Royal fern, *Osmunda regalis*, L., which I saw growing in its native state, in a situation where I did not expect it.

MOSSES.—*Orthotrichum Bruchii*, Brid.; *O. diaphanum*, Schrad.; *O. leiocarpum*, B. and S.; *Mnium hornum*, L.; *M. punctatum*, Hedw.; *Fissidens bryoides*, Hedw.; *Hypnum*

populeum, Hedw.; *H. arcuatum*, Lindl.; *Grimmia maritima*, Turn.

LICHENS.—*Cetraria islandica*, L.; *Lecanora vitellina*, var. *aurella*, Ach.; *L. ferruginea*, Huds.; *L. fuscata*, Schrad.; *L. rupestris*, var. *rufescens*, Hffm.; *Lecidea colludens*, Nyl.; *L. concreta*, Wahl.; *Lichina pygmæa*, Ag.; *Pertusaria melaleuca*, Sm.; *Physcia aquila*, Ach.; *Ramalina scopulorum*, Ach.; *R. calicaris*, Fr.; *R. fastigiata*, Fr.; *R. farinacea*, L.; *Ricasolia læta-virens*, Light.; *Thelotrema lepadinum*, Ach.; *Urceolaria scruposa*, L.; *Verrucaria nitida*, Weig.

DONSKNOWE, BARLOCO, and ORROLAND.

The same ridge ends in a rocky spur, but the same rock is continued at a less elevation, ending on the shore in the high grounds of Barloco (475 feet). We will follow the road from the top of Balmangan Glen past Stockmoss and turn to the right hand on the road along the rising ground. The specimens referred to were gathered within a mile of the road.

MOSSES.—*Orthotrichum saxatile*, Brid.; *O. affine*, Schrad.; *Bryum bimum*, Schreb.; *Pogonatum aloides*, Hedw.; *P. urnigerum*, L.; *Hedwigia ciliata*, Dicks.; *Hypnum splendens*, Dill.; *H. palustre*, L.; *H. filicinum*, L.

LICHENS.—*Collema cheileum*, Ach.; *Parmelia conspersa*, var. *insidiata*, Anzi; *P. physodes*, L., var. *recurva*, Leight., var. *labrosa*, Ach.; *P. lævigata*, Sm.; *P. saxatilis*, var. *furfuracea*, Schrad., var. *omphalodes*, L., var. *panniformis*, Ach.; *Physcia ciliaris*, L.; *Placodium murorum*, Hffm.

NOTES ON THE FLORA OF WEST INVERNESS.

By SYMERS M. MACVICAR.

(Read 9th March 1899.)

The districts referred to in the following notes are Arisaig, Moidart, and Ardnamurchan. The latter is, geographically, in Argyllshire, but it is included in West Inverness by Watson in "Topographical Botany," together with the other part of Argyllshire to the north of Loch

Linnhe. The geological formation of these districts has not yet been mapped out in detail, except in the western third of Ardnamurchan, which is composed of tertiary basalts, gabbro, with some limestone. The other parts are composed of schists, which, for the present, are named Dalradian. The rounded and frequently terraced hills of the basalts are readily distinguished from the bare rocky schistose formation; the latter having also a thin peaty soil, generally covered with heather, while the former has a deep soil covered with grass.

The flora of the two formations also differs, not so much in the presence or absence of particular species, as in the degree of frequency at which many occur. In this respect the flora of West Ardnamurchan more resembles that of the islands of the Inner Hebrides which have a similar formation, that is those from Mull to Skye. The most striking differences in the floras are the preponderance of *Calluna*, *Erica Tetralix*, and *E. cinerea*, and the abundance of natural wood on the schists. As the soil is more productive on the basalts, trees have been destroyed to a great extent for the sake of cultivation; and this has only been done in a small measure on the schists. In addition, the formation of the latter is of a more irregular character, giving better shelter for the growth of trees; and the wetter peaty soil is probably more suitable for *Betula pubescens*, the commonest of the native species. The poverty of this soil is illustrated by the abundance of *Molinia*.

The only distinctive plant of the basalts appears to be *Orobanche rubra*, but the presence in quantity of *Trifolium medium*, *Anthyllis Vulneraria*, *Rosa spinosissima*, *Galium verum*, and *Campanula rotundifolia* gives a distinctive character in many parts to the flora. Limiting the remarks to the immediate districts under consideration, we have the following plants which have been found only in West Ardnamurchan:—*Ranunculus sceleratus*, *R. bulbosus*, *Draba incana*, *Trifolium medium*, *Rubus Lindleianus*, *R. corylifolius*, *Galium boreale*, *Scabiosa arvensis* (colonist), *Petasites*, *Veronica Anagallis*, *V. Beccabunga*, *Orobanche rubra*, *Listera ovata*, *Orchis incarnata*, and *Carex distans*. The limestone is noticeable for the occurrence in quantity

of *Nasturtium officinale, Asplenium Ruta-muraria,* and *Scolopendrium.* The only locality in the district for *Veronica Beccabunga* is on this formation. *Ranunculus sceleratus* and *Veronica Anagallis* are confined to wet places on the shore; *R. bulbosus* to pastures adjoining a sand dune; *Rubus corylifolius* is frequent in the neighbouring island of Eigg; and *Listera ovata* occurs in Mull and Eigg.

It is interesting to note that several aquatics which are found in the low-lying islands of the Inner and Outer Hebrides, do not occur on this part of the mainland. These are *Batrachian Ranunculi, Hippuris, Apium nodiflorum, A. inundatum, Œnanthe Lachenalii, Alisma ranunculoides, Potamogeton filiformis,* and species of *Chara,* with the exception of *C. fragilis.* The flora of the coast north of Loch Linnhe may be charactised as being of three kinds:—(1) That of the basalts and gabbro, which includes part of Morvern and Ardnamurchan, Mull, Eigg, Rum, Canna, and Skye; (2) The Dalradian schists, to the borders of Ross-shire; (3) The Outer Hebrides, with one island in the Inner Hebrides, *e.g.* Tiree, the geological formation and physical features of which are those of this group. The island of Coll is of a similar Lewisian gneiss to that of the Outer Hebrides, and its flora has many features in common with it, but it also has much in common with that of the schists.

As is generally the case in the districts immediately bordering the west coast, the hills descend more or less steeply on most sides to nearly sea-level, so that the valleys are little elevated. This causes an absence of tableland, with the result that there is little soil, except at the bottom of the valleys; also that steep rocks descend to a low altitude. For this reason, the altitude at which cultivation can be carried on, and low ground plants ascend, is slight; while Alpine plants can find a favourable site at a low elevation, assisted in this latter case by the suitable moisture of the climate. Cultivation stops at about 400 ft., the fructicose *Rubi* at 500 ft., *Pteris* at an average of 1250 ft. on the south side of the hills, and 900 ft. on the north side. The highest limit on the hill sides of copses is about 700 ft. The highest limits

observed of isolated specimens are, *Ilex Aquifolium*, 680 ft., 800 ft.; *Pyrus Aucuparia*, 1400 ft., 1600 ft., 2200 ft. (the last only eight inches in height); *Ulmus montana*, 600 ft.; *Betula pubescens*, 1000 ft., 1250 ft., 1350 ft.; *Corylus Avellana*, 850 ft.; *Quercus Robur*, 750 ft.; *Salix aurita*, 1400 ft., 1600 ft., 1800 ft.; *S. Caprea*, 1050 ft. The range of cultivation and of plants cannot here be taken as a test of the climate, except when compared with those on hills of nearly equal height and bulk, because as a rule, the higher the hills are, the higher will plants ascend, with the more plentiful soil and surface room. In this district there are five hills between 2800 ft. and 2900 ft. altitude, the highest being 2895 ft.; while there are about the same number of upwards of 2000 ft., all being on the schistose formation. The highest hill on the basalts is only 1729 ft., and is too low for purposes of comparison. The moors, that is where there is a more or less complete covering of *Calluna*, reaches to between 1400 ft. and 1500 ft.

There are many lochs in the district, being mostly on the hills between 300 feet and 1100 feet altitude. Dr. Magnin, in his "Recherches sur la Végétation des Lacs du Jura," separates the lakes into three divisions, "lac normal," "lac de tourbières," and "lac-étang." The first is the common form, with rocky or stony shelving sides. The second is the peat loch, always of small size in West Inverness. It is without shelving sides, the water being deep to the margin. The "lac-étang" need not be considered in regard to this district. Many of our Highland lochs have features of the first two combined, in some parts with rocky sides, in others peaty. Magnin then divides the flora of the lakes into—(1) a zone of *Carex*; (2) of *Phragmites*; (3) of *Scirpus*; (4) of *Nuphar*; (5) of *Potamogeton*; (6) of *Characeæ*, according to the prevalence of certain species. There is no definite line between the zones, most of the plants extending to one or more of the others, but each has its preponderating flora. In this district somewhat similar divisions may be used, but there is no *Scirpus* zone, as *Scirpus lacustris*, which is the plant taken by Magnin, is very rare, and there is no other to take its place. After an examination of many of the lochs

by dragging and otherwise, I would give the zones of the "lac normal" with their series of plants as—(1) *Carex* zone. This is the marshy ground round the lochs. In it we have *Carex rostrata, C. filiformis, C. limosa, Rhynchospora alba, Menyanthes, Sparganium minimum, Malaxis paludosa, Pinguiçula lusitanica, Drosera rotundifolia*, and *D. anglica*. (2) *Subularia* zone, a zone of shallow water with gravelly bottom outside the *Phragmites* zone. In this are *Subularia aquatica, Ranunculus scoticus*, Marshall (*R. Flammula*, var. *petiolaris*, Lange), the first appearance of *Littorella lacustris* and *Lobelia Dortmanna*, with *Montia, Callitriche*, and *Ranunculus Flammula*. (3) *Phragmites* zone. In this we have *Phragmites, Cladium, Carex rostrata, Scirpus palustris, Sparganium affine, Isoetes lacustris, Nymphæa alba* as a small state, *Potamogeton polygonifolius, P. natans* occasionally, *Littorella, Lobelia, Menyanthes*, and *Myriophyllum alterniflorum*. (4) *Nuphar* zone. This is the home of *Nymphæa alba* and *Nuphar lutea, Potamogeton natans* and deep-water forms of *P. polygonifolius*, with *Myriophyllum* and some *Lobelia*. (5) *Potamogeton* and *Characeæ* zone. Characterised by the presence of *Potamogeton prælongus, Nitella translucens, Juncus supinus* with filiform leaves, with *Potamogeton perfoliatus, Chara fragilis, Utricularia minor*, and *U.* "*vulgaris*." (There is some doubt whether our *Utricularia* is *vulgaris* or *neglecta*, as it does not flower.) *Chara fragilis* and the species of *Utricularia* are frequently found in the shallow water of the "lac normal" where there is mud, but they are among the few plants usually dragged from the deepest zone. In the peat lochs, the plants which prefer a stony bottom are generally absent, and near the margins are *Phragmites, Cladium, Menyanthes, Nymphæa, Nuphar, Nitella opaca, Chara fragilis*, and *Utricularia*, including *U. intermedia*.

As the surroundings of the peat loch are usually more marshy than with rocky lochs, we have the *Carex* zone most marked in them. In those parts of the rocky loch, where steep rocks come to the water's edge, there is generally only deep water, and in this case the *Nuphar* zone is at the margin. In the West Highlands, as *Nymphæa* is a much more common plant than *Nuphar*, the zone would be more appropriately given its name. Both *Nymphæa alba*

and *Nuphar lutea* occur in a small state, which is generally due to their being in shallow water, or in lakes at a higher altitude. The small state of *Nuphar lutea* from this district was at one time referred to *N. intermedia*; but this latter plant, which is probably a hybrid between *N. lutea* and *N. pumila*, has not been found here. *Lobelia Dortmanna* is abundant in lochs up to about the same altitude as *Nymphæa*, which is 1100 feet. *Potamogeton prælongus* was, until recently, considered to be rare on the west coast, but it occurs in most of the deeper lochs in this district. As it is usually confined to the deeper parts, it is seldom seen except by dragging. This is also to some extent the case with *Nitella translucens*, which sometimes occurs in such large masses in deep water as to exclude other vegetation. In such places it is sterile, with elongated branches; but this species is also found occasionally in shallow water.

A considerable part of the low ground of the district is covered by a moss, which is less than twenty feet above sea-level. Over most of it, and extending a short distance up the higher adjoining ground, is *Rhynchospora fusca* in great abundance. This moss occupied at one time the Loch Shiel valley, but it has been divided into two parts by a raised beach, on which now stands the village of Acharacle. The plant occurs on both sides of the old beach, and has probably spread from the higher ground after the last elevation of the land. The only other locality in Scotland where the *Rhynchospora* has been found is in Wigtownshire, where it was discovered by Mr. M'Andrew in 1887. It is known at sight from the autumnal brown state of *R. alba*, which is a common plant on this coast, by the latter growing in less compact patches.

The number of species, excluding casuals and aliens, known from the district may be given as 520. This is taking the "London Catalogue," 9th edition, as the standard, except with *Rubus* and *Hieracium*, where I have followed Syme's "English Botany." In this the fructicose *Rubi* are given as one species, and the hawkweeds are mostly limited to the species of Backhouse. In giving Watson's types under which the plants would be placed, some of the segregate brambles would probably

come under the English type, and some of the recently described hawkweeds under the Highland and Scottish types; but the distribution and relative value of these plants are less known than that of our more firmly established species.

There are thirty-six species which belong to the Highland type. I have added their range in altitude in the district—

Thalictrum alpinum, 2860—800 ft.
Draba incana, 0.
Silene acaulis, 2860—1950.
Alchemilla alpina, 2870—850—300.
Epilobium anagallidifolium, 2700—1800.
Sedum roseum, 2200—0.
Saxifraga stellaris, 2000—700.
—— azoides, 2150—0.
—— oppositifolia, 2860—1000.
Cornus suecica, 1600.
Galium boreale, 100.
Hieracium holosericeum, 2800—2300.
—— eximium, 2800—2500.
—— lingulatum, 1800—1500.
—— senescens, 1800—1700.
—— anglicum, 1600—0.
—— Schmidtii (pallidum p.p.), 1400—1000.
Hieracium nitidum, 500 (?)
—— flocculosum, 500 (?)
Gnaphalium supinum, 2800—2300.
Saussurea alpina, 2300—1400.
Arctostaphylos Uva-Ursi, 1000—0.
Vaccinium Vitis-Idæa, 2700—0.
Polygonum viviparum, 2000.
Oxyria digyna, 2100—700.
Salix herbacea, 2870—1850—1600.
Juncus trifidus, 2300—1550.
—— triglumis 2700—2100.
Luzula spicata, (?)—1900.
Carex pauciflora, 1100—600.
—— rigida, 2800—1500.
Cryptogramme crispa, 2700—2200.
Asplenium viride, 1800—0.
Lycopodium alpinum, 2500—300.
Selaginella selaginoides, 1500—0.
Isoetes lacustris, 1900—0.

The low ground locality for *Alchemilla alpina* is anomalous in the district, being among boulders remote from the higher hills. *Sedum roseum* (*Rhodiola rosea*) has not been observed between the shore rocks and 700 feet. *Saxifraga azoides* and *Selaginella* probably mount higher than the altitudes given. *Asplenium viride* has only been met with on one rock on the hills, at 1800 feet. It is more frequent, though a rare plant, from 780 feet to sea-level. *Lycopodium alpinum* is seldom seen below 1200 feet. *Cornus suecica* and *Polygonum viviparum* are very rare. *Hieracium nitidum* and *H. flocculosum* were found by Mr. W. F. Miller in 1895. The altitudes given of these two hawkweeds are only to be considered as approximately correct.

To the Scottish type belong thirty-seven species—

Thalictrum dunense.
Trollius europæus.
Subularia aquatica.
Drosera anglica.
Vicia sylvatica.
Prunus Padus.
Rubus saxatilis.
Circæa alpina.
Saxifraga hypnoides.
Parnassia palustris.
Ligusticum scoticum.
Antennaria dioica.
Cnicus heterophyllus.
Crepis paludosa.

Lobelia Dortmanna.
Pyrola media.
Orobanche rubra.
Ajuga pyramidalis.
Lamium intermedium (colonist).
Galeopsis versicolor (colonist).
Mertensia maritima.
Pinguicula vulgaris.
Trientalis europæa.
Empetrum nigrum.
Rumex domesticus.
Salix phylicifolia.
Pinus sylvestris.
Goodyera repens.
Listera cordata.
Habenaria albida.
Potamogeton prælongus.
Scirpus rufus.
Carex dioica.
—— limosa.
—— filiformis.
Phegopteris polypodioides.
—— Dryopteris.

Of these, *Trollius*, *Rubus saxatilis*, *Saxifraga hypnoides*, *Antennaria dioica*, *Pinguicula vulgaris*, *Empetrum*, and *Phegopteris polypodioides* ascend above 2000 feet. *Carex dioica*, perhaps, also does, but my highest altitude for it is 1800 feet. *Campanula latifolia* and *Elymus arenarius* also belong to this type, but are aliens.

There are thirteen species belonging to the English type—

Nuphar lutea.
Drosera intermedia.
Lythrum Salicaria.
Galium Mollugo (colonist).
Scutellaria minor.
Centunculus minimus.
Samolus Valerandi.
Cephalanthera ensifolia.
Scirpus Tabernæmontani.
Cladium jamaicense.
Trisetum flavescens (colonist).
Festuca rottbœllioides.
Lastræa spinulosa.

Also the following aliens:—*Inula Helenium*, *Lactuca muralis*, *Sambucus Ebulus*, and *Convolvulus sepium*.

To the Atlantic type belong seven species—

Hypericum Androsæmum.
Sedum anglicum.
Carum verticillatum.
Pinguicula lusitanica.
Rhyncospora fusca.
Hymenophyllum Tunbridgense.
—— unilaterale.

To the intermediate type belongs *Vicia Orobus*, and to the local type *Utricularia intermedia*. The former is rare, the latter is common, occurring up to 1000 feet, and in some localities is the prevalent species of the genus. There is no native plant in the district which belongs to the Germanic type. The only species of this type, *Weingærtneria* (*Corynephorus*) *canescens*, occurring in two localities in Arisaig, was introduced by the late Mr. Æneas Macdonell, Morar.

The remaining species belong to the British type.

Ranunculus repens, L.—This species is limited to ground near cultivation, and to roadsides.

Cochlearia officinalis, L.—Only occurs inland on some islands in a hill loch where gulls breed. The seeds have probably been carried attached to the birds' feet, or on decayed fish brought by them from the shore.

Sagina procumbens, L.—Specimens are occasionally to be found with spinous ciliate leaves; the ciliation varies much in quantity, being confined to one or two leaves, or occurring on all.

Sagina nodosa, Fenzl.—The glandular form is found with the typical plant. This species only occurs near the shore.

Spergula arvensis, L.—The only form of this plant which I have seen is var. *sativa* (Bœnn).

The following fructicose *Rubi* are found in the district:—*R. fissus*, Lindl., *R. suberectus*, Anders., rare; *R. plicatus*, W. and N., rather common; *R. carpinifolius*, W. and N., rather common; *R. Lindleianus*, Lees, rare; *R. pulcherrimus*, Neum., locally common; *R. dumnoniensis*, Bab., locally common; *R. villicaulis*, Kœhl. (*R. insularis*, F. Aresch.), common; *R. villicaulis*, var. *Selmeri*, Lindeb., very common; *R. hirtifolius*, Muell. and Wirtg., var. *danicus*, Focke, uncommon; *R. mucronatus*, Blox., rather common; *R. infestus*, Weihe, rather rare; *R. rosaceus*, var. *infecundus*, Rogers, locally common; *R. corylifolius*, Sm., rare. In the neighbouring district of Sunart I have found *R. Borœanus*, Genev., which does not appear to have been recorded elsewhere from Scotland.

Alchemilla vulgaris, L.—The common plant is the var. *alpestris* (Schmid). It is local in its distribution, being rare in parts, and plentiful in others. Var. *filicaulis* (Buser), also occurs, but is much less frequent.

Drosera intermedia, Hayne.—The scape is generally shorter than the leaves in this district. Although the three species of *Drosera* may be found together, they frequently have a local distribution of their own, each species being alone found in some localities.

Epilobium adnatum, Grisebach.—Very rare. This is one of the few localities in which it has been found in Scotland. The Rev. E. S. Marshall, our chief authority on the genus, named the specimens, as well as the hybrid *adnatum* × *obscurum*.

Viburnum Opulus, L.—Only a few stunted bushes are

found in widely separated localities. It appears to be a decreasing species, and seldom forms berries.

Galium palustre, L.—The plant of this coast has the stems and margins of leaves always more or less rough with prickles, and the cyme varies accordingly to whether the plant be in dry or wet soil. *G. uliginosum* has been recorded from this district, but the specimens so named which I saw were a marsh form of *G. palustre*. I have looked without success for *G. uliginosum* on the mainland and inner islands of this part of the coast.

Valerianella olitoria, Poll.—I had formerly thought this to be a colonist, but I now consider it a rare native on the sandy shore. It occurs in similar places on the island of Coll, remote from cultivation.

Erica cinerea, L.—The white-flowered plant appears to be a permanent form, at least much more so than in the case of *Calluna*. I have known individual plants for some years, one for eight years; and a friend has known a plant in its native locality for more than thirty years. I have not known a plant of *Calluna* to retain white flowers in its native locality for more than five years, usually less. The leaves of the white-flowered *Calluna* are lighter green than in the normal plant. It is probably a more tender condition, but whether it returns to the ordinary plant or dies out, I have not been able to ascertain.

Armeria maritima, Willd.—The range in altitude of this plant on the hills is 1550 ft. to 2860 ft. I have not seen it between the former height and the shore. Our mountain form is not the var. *planifolia*, Syme.

Veronica serpyllifolia, L.—The common low ground plant appears always to have pubescent capsules.

Euphrasia officinalis, L.—The forms known from this district are—*E. borealis*, Towns.; not uncommon in uncultivated pastures, especially about the shore. *E. brevipila*, Burnat and Gremli.; very common, most frequently in the more cultivated pastures. *E. curta*, Fries.; I have only found this in one place at 1300 ft. altitude. *E. occidentalis*, Wettst.; Mr. Townsend found this in short pasture at Morar Bay, Arisaig, also the hybrid *occidentalis* × *brevipila*. *E. gracilis*, Fries.; very common in

rather dry peaty ground, but sometimes in loamy soil. *E. gracilis × brevipila*; found by Mr. Townsend near Shiel Bridge in Ardnamurchan. *E. scotica*, Wettst.; local, but not uncommon in the wetter moors.

Bartsia Odontites, var. *littoralis*, Reichb.—I found this in 1896 on shingly shore in Ardnamurchan. It was then new to Britain, but has since been found in the extreme north of Scotland. It is nearer var. *verna* than var. *serotina*, but the plant from this district is conspicuous by its branches, when present, being nearly erect and straight.

Ajuga pyramidalis, L.—This species occurs here at its lowest reported altitude in Britain, at 15 ft. to 20 ft. above sea-level. Hewitt C. Watson found it to be more of a biennial than a perennial in his garden, and this was the experience of Mr. Arthur Bennett; but in its native locality it is perennial. I have watched plants for six years. In autumn, stolons are emitted from one or more sides, from which arise young plants. When the central piece dies, the others form separate plants.

Plantago maritima, L.—Rarely occurs on the hills below 1800 ft., but in some places it can be traced from the shore upwards. It spreads on the low ground along footpaths when gravelly, but not when peaty.

Myrica Gale, L.—Female catkins are uncommon in comparison with the abundance of those of the male.

Betula verrucosa, Ehrh.—This is native, but not common. As it is the only species which is planted, it will probably spread.

Pinus sylvestris, L.—There are still a few native trees in Moidart at the head of Loch Shiel. Near this locality, but on the Argyllshire side of the loch, there is a fairly large native wood on the hill side.

Listera cordata, R. Br.—Common, and locally plentiful, among heather. It is one of the early summer plants which, later in the year, are apt to be considered uncommon. The same may be said of *Botrychium Lunaria*, which can be seen in spring on almost every dry pasture.

Goodyera repens, R. Br.—Very rare. Found by Mr. W. F. Miller, in 1874, in the pine woods near Kinlochailort.

Cephalanthera ensifolia, Rich.—This seems to be a decreasing species. It does not appear to form seed, and is only found in small quantity in a few copses.

Habenaria conopsea × *albida*.—This interesting hybrid, determined by Mr. Rolfe, was found by Mr. H. N. Dixon, in Arisaig, in June 1898. It has not before been found in Britain. In the "Journal of Botany," 1898, p. 352, will be found the distinguishing points of this hybrid.

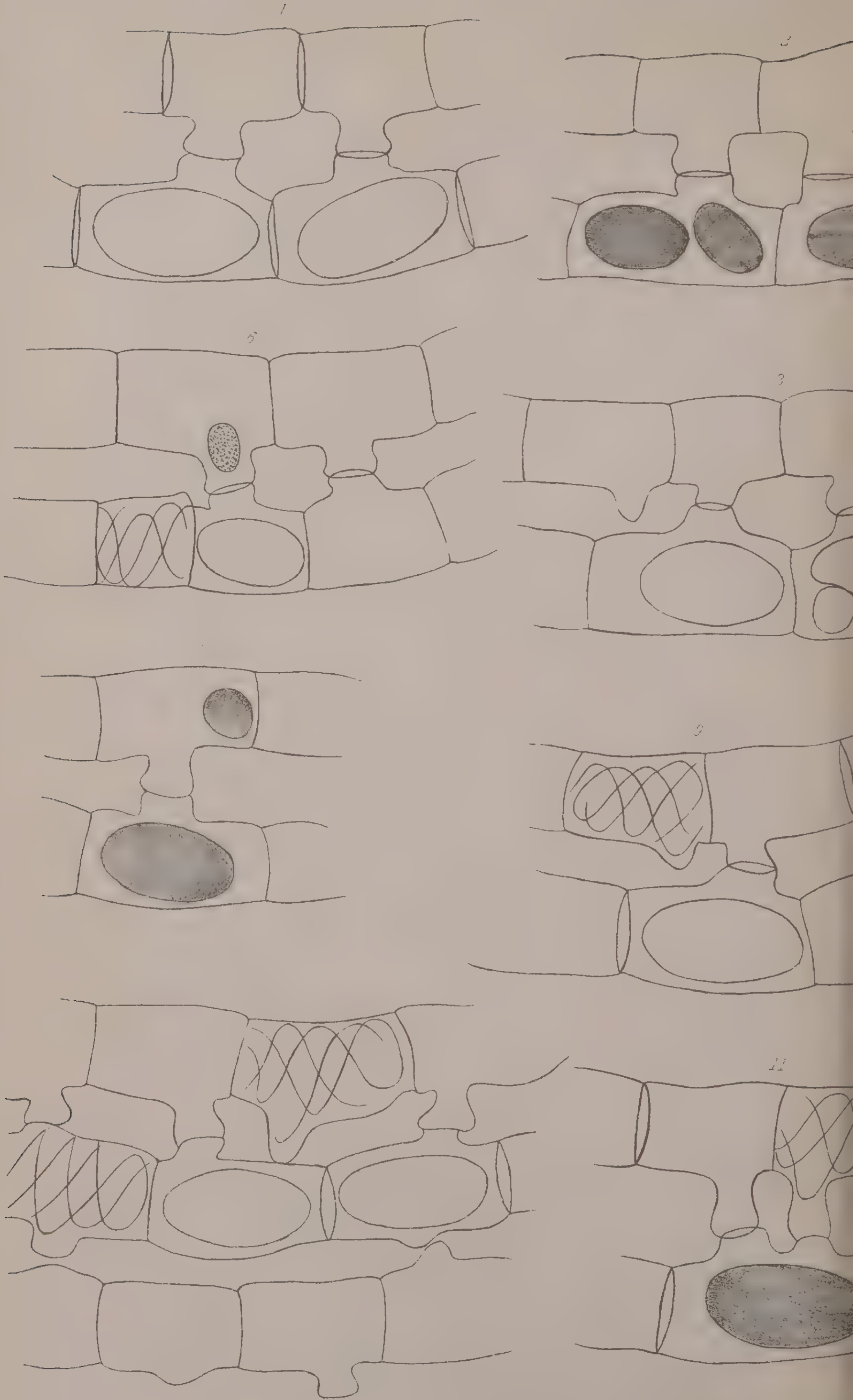
Habenaria bifolia, R. Br., and *H. chloroleuca*, Ridley.—These are both common in early summer in suitable ground.

Juncus tenuis, Willd.—Found by Mr. W. Grant, in 1896, at Arisaig in a garden, and by the side of a cart track near houses. In the following year I found one plant in Moidart in the middle of a disused road. In 1898 it had increased to several plants. I also found one plant in another locality near a poultry yard. The evidence available from its stations in the district support the view that this increasing alien was introduced by means of American hay, and, perhaps, other feeding material.

Carex remota, L.—Although generally distributed, only a few plants are found in any single locality. I have noticed in one case that it is prevented from seeding by being cropped by cattle, who at once detect it when the stems rise above the surrounding herbage.

Carex fusca, All. (*C. Buxbaumii*, Wahl.).—The only station for this rare species in Britain is in this district, where it was discovered by Mr. W. F. Miller in 1895. It only grows in small quantity, but it is in a very favourable locality, and would appear to be in no danger of becoming extinct, except through injudicious collectors. As it is already extinct, or nearly so, in its only Irish station, it is to be hoped that consideration will be shown to it in its Scottish locality. An interesting extension of continental range for the species was found in 1896 in its occurrence in the west of France, in the department of Manche.

Carex extensa, Good., var. *pumila*, Anders.—If this be the same as var. *minor*, Syme, it does not appear to be worth varietal rank. In comparative length and curvature of



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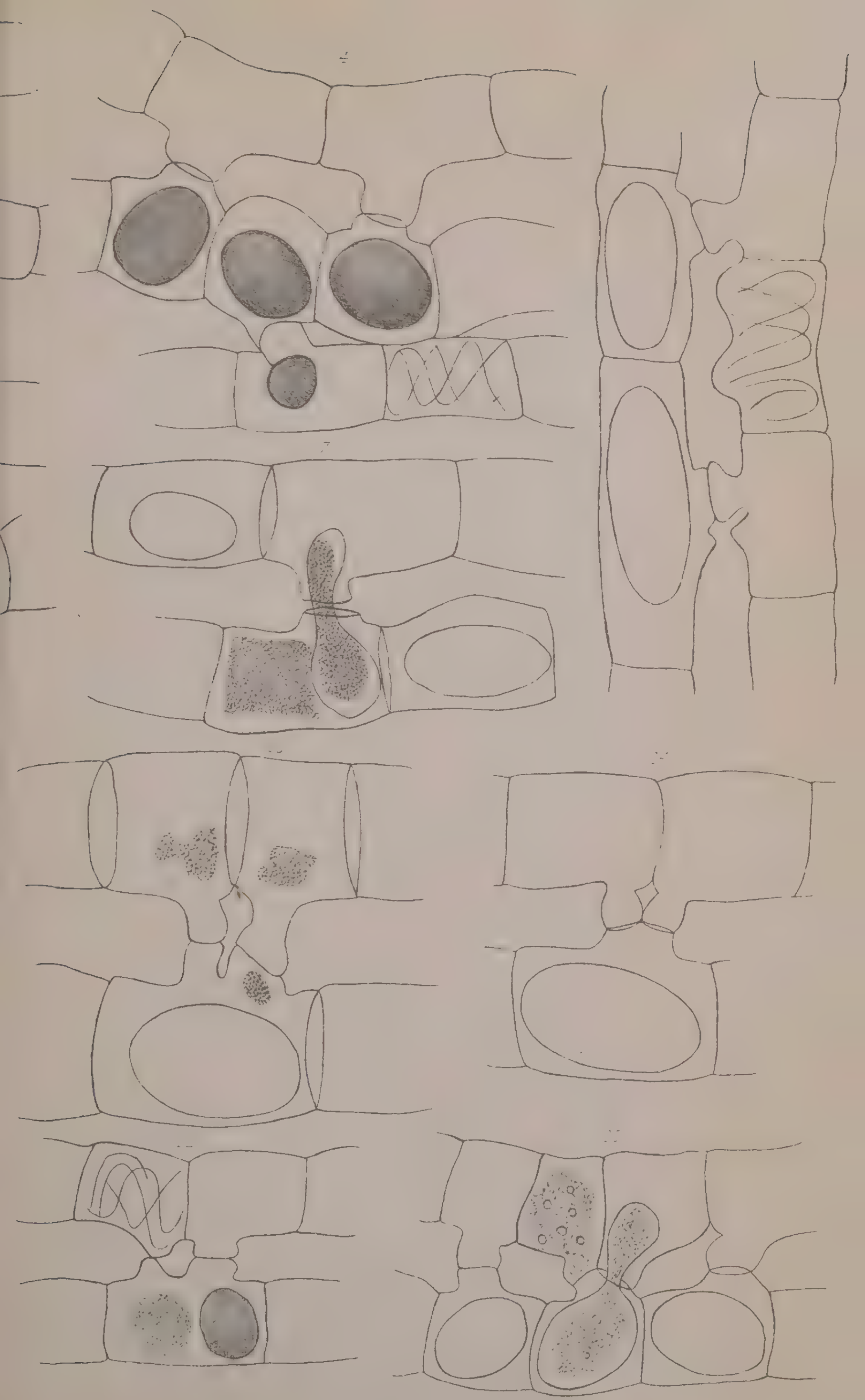


stem the species varies greatly, intermediates between the type and variety being frequent. In salt marshes frequently submerged, the plant is most dwarfed, as are others in the same situation.

Carex rostrata, Stokes.—The leaves are narrow and much channelled in marshes and shallow water, becoming broader and flatter in deeper water. There is a form which grows with the common plant that does not appear to depend for its peculiarities on the surroundings. It is a more robust plant, with the leaves broad and flat, or nearly so, giving it a conspicuous appearance. Mr. Arthur Bennett thinks it may be the form *planifolia*, Norman, *Fl. Arc. Norwegiæ.*

Hymenophyllum Tunbridgense, Sm.—This species can be known at sight from *H. unilaterale* by its broader fronds spreading out horizontally, instead of being convex as in the latter. It is also confined to damp shady rocks on the low ground, while *H. unilaterale* frequently grows in exposed places, and mounts to 2500 ft. altitude.

Osmunda regalis, L.—Still to be found in many places, but has been exterminated in some of its localities by professional dealers. There is little danger of its complete extinction, as it sometimes occurs on practically inaccessible islands on the hill lochs.

On Abnormal Conjugation in Spirogyra.

By R. A. Robertson, M.A., B.Sc. (With Plates.)

(Read 9th March 1899.)

Early in 1897 was commenced a series of experiments on fresh-water algæ, to elucidate some points regarding the sexuality of the group. These experiments are still in progress. In the meantime there has appeared a very exhaustive account, with a bibliography of the Conjugatæ by W. and G. S. West, in "Annals of Botany" (March 1898). Some of the results which I obtained in experimental laboratory cultures, particularly of Spirogyra, and which I had regarded as pathological or induced, are there

described as occurring in nature. A few variations are not described in that paper, and of these the following note gives some details. It is interesting to note that all these were found occurring in one culture of Spirogyra. It was impossible to mount the smallest particle of the material without finding in it some abnormality. The particular Spirogyra was not determined, but it was one of the common species of medium size with serrate-edged chromatophores and large pyrenoids.

Gatherings of the material, which had been compressed into small tubes, were turned out into a shallow white glazed dish with just as much water as sufficed to keep the filaments moist. The culture was exposed to the diffuse light of a north window, and kept at the ordinary temperature of the laboratory. Tap water was supplied at long intervals as the specimens dried. The specimens were allowed to become dry inadvertently on several occasions. The plants, which were matted and coiled together in inextricable confusion, were at first in vegetative condition, but after some weeks all passed into the reproductive stage. Part of the material was examined fresh, the remainder was fixed and preserved in a solution of acetic acid.

In Spirogyra in nature various modes of conjugation are found, the commonest being the so-called *Scalariform*. This may be of two types—the normal *uniform*, where the movement of the protoplasts between the filaments takes place in one direction only, so that one filament is emptied and the other filled with zygospores. The other variety of Scalariform is known as *cross conjugation*, where the movement of the protoplasts between the filaments is not uniformly in one direction, so that ultimately each filament contains a number of empty cells, as well as several cells containing zygospores. This variety is so rare as to be practically abnormal.

An interruption in conjugation may result in a kind of false cross conjugation, where, although the conjugating tube is formed, there is no movement of the protoplasts, but each rounds itself off into an azygospore.

A more infrequent mode than normal scalariform, and, possibly, to be regarded as abnormal, is *lateral*, where conjugation takes place between adjacent cells of the same

filament. A loop tube is formed at contiguous ends of neighbouring cells, and through this one protoplast moves into the adjacent cell. This, as a rule, occurs in groups of four cells—the zygospores being formed in the central two cells, while the outer cells are empty.

Curiously enough, neither cross nor lateral conjugation occurred in the artificial cultures, although both might have been expected to be of common occurrence. The modifications were all variations of the normal scalariform; false cross conjugations were frequent, and interrupted conjugations very abundant.

A zygospore may be the result of the conjugation of two protoplasts, male and female; or of three, two males and one female. Further, female filaments are described as being very much the more abundant, so that conjugation between one male and several female filaments is very common. West confirms this by figures.

The converse was found to be the rule in my artificial cultures; females were very much in the minority, and bundles of male filaments from three or more were found around one female, conjugating at intervals along their length. Starvation tended, apparently, to increase the number of males. Such cases as in Figs. 21 and 25 were found in every mount, while the equality, as seen in Fig. 24, was very uncommon. The preponderance of males was seen even in the conjugation between two filaments, where two male cells conjugating with one female were found, as well as extremely numerous cases of such conjugation interrupted.

None but imperfect conjugations of two females and one male occurred, and that rarely.

Again, Bennett ("On Reproduction in the Zygnemaceæ," "Jour. Lin. Soc.," 1884, vol. xx. p. 430) states that it is possible, before conjugation has actually occurred, to distinguish the female from the male filament, by the larger size of the former, and by the female part of the conjugating tube being shorter and wider. This was combated by Bates ("On Sexuality of the Zygnemaceæ," "Jour. Quekett Micros. Club," 1885, sec. ii. vol. ii. p. 104). West also regards Bennett's distinction as of little value, and confirms Bates'.

There was no uniformity on this point in my specimens, sometimes the one, sometimes the other was the larger cell, occasionally the male was the shorter and thicker tube, at other times, when failure of conjugation occurred, the female tube was abnormally long and slender, although never attaining the dimensions of a rhizoid, as described by West. When three cells conjugated, sometimes the female sent out two tubes to meet the corresponding ones of the two males, at other times one broad tube faceted for the males, the facets sometimes carried to extreme, so as to appear an incipient *branching.*

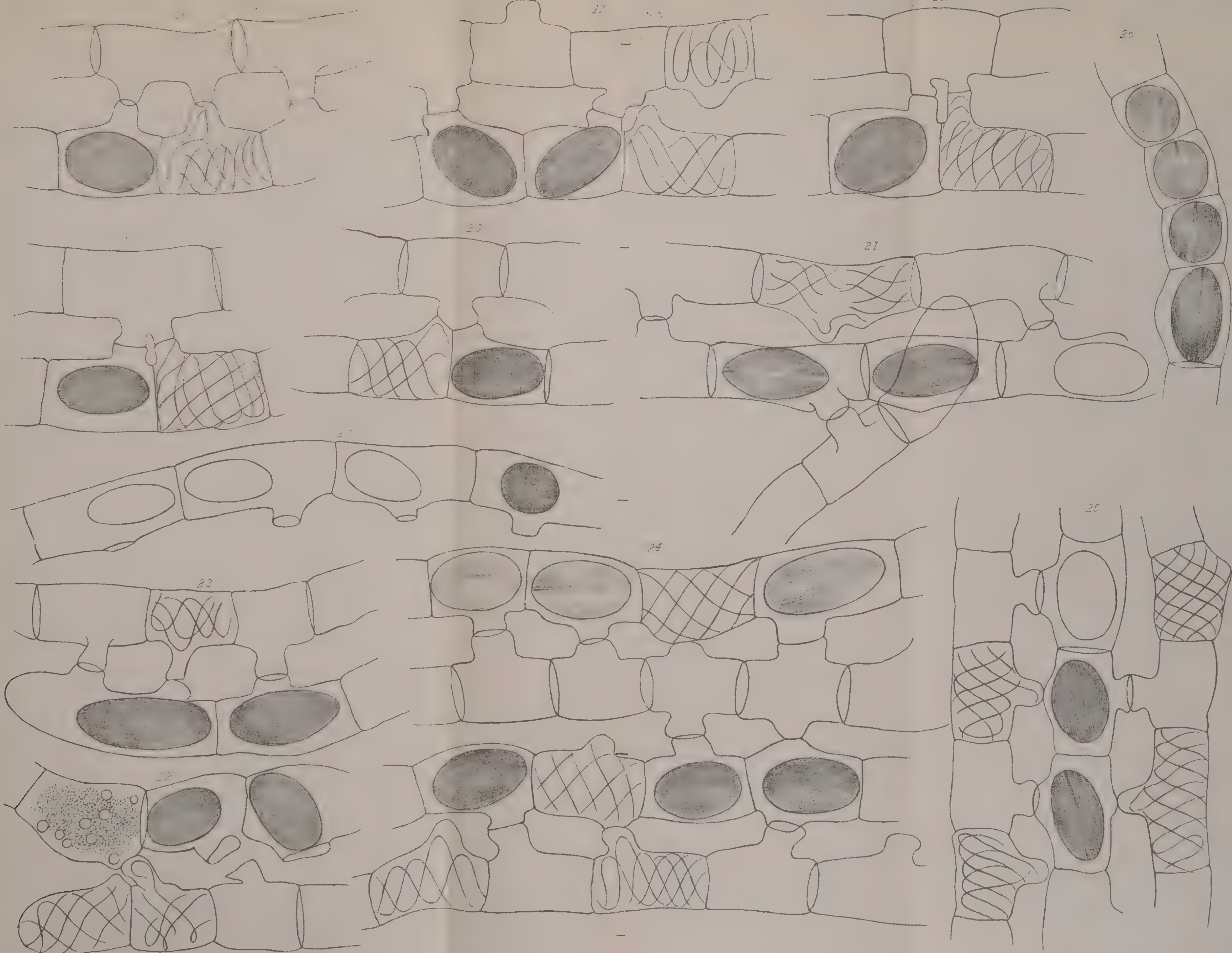
Again as to the orientation of the conjugating tubes: when a cell sent out two tubes, these might be on opposite sides of the cell, and practically in the same plane, or they might be in any plane at any angle to the first one.

The variation affected the size of the zygospore; in the same filament there were considerable differences in this respect. See Figs. 26 and 27.

Formation of the zygospore in the conjugating tube is said never to occur in nature. In several specimens of interrupted scalariform conjugation, an interesting intermediate condition occurs. The zygospore is dumb-bell shaped, and stretches through from cell to cell. That this is not a protoplast in passage, but an actual zygospore, is shown by the rounded-off appearance of the mass, and by the presence of the characteristic membranes. In other cases, where azygospores were found, one of these, the smaller, was partly in the conjugating tube.

Considering first the cases where conjugation takes place between two cells—

Fig. 1 shows the normal scalariform mode. In Figs. 2 and 3 is seen an interesting case where, after normal conjugation, the female cell contains two zygospores of nearly equal size in the former, of very unequal size in the latter. Figs. 4 and 5 show azygospores. A small part or none of the protoplasm has passed over, and the two protoplasts have rounded off, encysted, and become spores. In Fig. 6 a similar condition is seen, with the additional interest that the smaller of the two spores, the male, is partly in the conjugation tube. This forms a transition to the following. Fig. 7 depicts a condition



R. A. R., del.

SPIROGYRA.

noteworthy on several grounds. It shows an example of false cross conjugation. In addition, there is also seen a case of partial conjugation. Of the female cell, only a part of the protoplast has conjugated, the other part remaining sterile. The zygospore, further, is dumb-bell shaped, the ends of the dumb-bell being in the male and female cell respectively, and the constricted handle being in the conjugation tube. The spore, except for its peculiar position and shape, appears perfectly normal, having membrane, and so forth. This might be regarded as a case of reversion, pathologically induced to a primitive Zygnema type, where conjugation took place in the tube itself.

Taking next, examples of conjugation between three cells—two males belonging to one filament, and one female to another, or belonging to three different filaments. Of the latter condition no completed conjugations were found, although all stages of attempted conjugation on these lines are found, as see Figs. 24 and 25. Of the former, all stages, from the incomplete to the complete condition, occurred, and that very abundantly. Figs. 9 and 10 show two male cells which have sent out tubes towards one female, which has developed one tube, by which it conjugates with one of them. In Fig. 11 is seen the next case, where the female has developed two tubes, meeting those from the males, but only one male has conjugated. Examples of this were very numerous. Fig. 12 shows a curious condition, the same events have occurred as in 11, but only part of the female protoplast has conjugated and rounded off to form the zygospore; another part has apparently remained sterile. In Fig. 13 is seen the perfect condition, where two males have conjugated with one female through two sets of conjugation tubes. Those of the female are now so close that they might be regarded as branches of one broad tube. Traces of protoplasm still remain in each male cell, and a detached fragment near the mouth of one of the female tubes. In West's paper is figured a specimen where the conjugation is complete.

Another series might be figured where the female sends out one broad tube faceted to meet the two tubes from the two male cells. All intermediate stages of this also

occurred; the ultimate member of the series, where complete conjugation has occurred, is figured in Fig. 14.

Fig. 15 shows a case of a dumb-bell shaped zygospore with three cells similar to that in Fig. 7 for two cells. West figures a further case for three cells, where, owing to the lateral pressure of one of the male tubes, conjugation by way of the other is prevented, and azygospores result.

Figs. 16 to 20 illustrate the case of attempted conjugation between three cells, two of which are female and one male. In Fig. 16, the male cell sends out two tubes to meet those of the two females, but conjugates with one of them. Fig. 18 is a transition to the following. In Figs. 17 and 19, the single male cell sends out a broad tube which bifurcates, each branch meeting a tube from each female cell. In Fig. 20 is seen the condition where the single broad male tube is faceted to meet the two females produced in very close proximity (as if for lateral conjugation).

The ultimate stage of this series, where one male would fertilise two females, either by way of one or by two separate tubes, was very carefully looked for. This would involve the division of the male protoplast immediately prior to the act of conjugation. That this might occur might be reasonably expected from what has been already described as occurring in Fig. 7, which is the converse where only part of the contents of a female cell have conjugated with the male gamete, the other part of the female protoplast remaining sterile. Given that this sterile part conjugated with a male cell, then there would be two zygotes in the female cell as the result of conjugation of three, and the opposite case for the single female cell would be realised. Examples were looked for where active nuclear division occurs at the apical cells of the filaments, and, although such exhibited irregularities of conjugation depicted in Figs. 21, 22, and 23, the particular case was not met with.

A study of artificial cultures leads one to note particularly the nice adaptation to environment displayed by the algæ. The internal forces of the cells appear to be so accurately balanced by the external conditions that a sort

of unstable equilibrium results. The disturbance of this equilibrium may come from within or without. Variations in the external conditions induced by artificial cultures, a limited supply of nourishment, partial desiccation, maximum exposure to light, close competition between the filaments compressed into a limited area, would appear to be sufficient to disturb seriously this equilibrium and to induce to the maximum extent those profound physiological changes involved in the passage from the vegetative to the reproductive state of protoplasm. The change induced in this case is apparently so excessive as to be of a pathological character, inducing a wave of abnormality, as it were, to pass along each filament, the visible evidence of which we have in the numerous curiosities of conjugation.

ON THE HISTOLOGY OF SOME FOSSIL WOODS (Pt. 2). By R. A. ROBERTSON, M.A., B.Sc. (With Plates.)

(Read 9th March 1899.)

The specimens of silicified woods described in this and a former paper form part of the Geological Collection in the St. Andrews University Museum, to the Director of which, Professor W. C. M'Intosh, I am indebted for kind permission granted to examine them.

Specimen 2, Plate I., is a remarkably pretty piece of stem, measuring about 41 mm. in length. Owing to a not inconsiderable amount of eccentric growth, the section is irregularly ovate, the pith being in the narrower end. The greater diameter is 54 mm., with radii of 39 and 15 mm. respectively, the shorter diameter is 31 mm., and its radii 17 and 14 mm. respectively.

The pith, though small, is distinct, and the earlier rings are quite concentric to it, while the later rings are more or less incomplete, thinning off greatly or altogether on one side, so as to be crescentic in shape, recalling particularly the similar arrangement in a cross section of canker-infected larch stem. Star-shakes, following the lines of the medullary rays, are present. Looking at the

polished cross section, one notices particularly a marginal band, creamy white in colour, and of variable breadth from 2 to 5 mm., passing right round the stem. The remainder and larger part of the section enclosed by this is of a mottled dark colour, in fact, by a fortunate coincidence, the tint of a photomicrograph fairly well corresponds to that of the actual specimen. While the minute structure is on the whole very well preserved throughout, it is most exquisitely so in the white peripheral zone. It is doubtful whether this difference in colour, accompanied as it is by a difference in the degree of perfection of preservation of the anatomical structure, is to be ascribed to peculiarities of silicification, or represents some primary differentiation in the original wood itself into alburnum and duramen. I am inclined to believe that the latter is the explanation.

With the naked eye, one can discriminate the annual rings, sharply limited by a thin white line; medullary rays, as delicate sinuous threads on the darker matrix, of marked continuity; tracheæ, as small dark spots of uniform distribution.

Viewed microscopically, the wood appears to have been composed of a ground mass of fibres, quadrangular in section, and arranged in very regular radial rows: among these are embedded tracheæ, equable in size, not very abundant, but uniformly distributed. The fibres average 0·01875 mm. in diameter, while the pores measure 0·1071 mm. in tangential and 0·1285 mm. in radial diameter. The pores occur singly, or often in radial groups of two to six or more.

The medullary rays are numerous, about 60 per 5 millimetres; they are of two sizes, and are not very uniformly distributed. Their breadth varies from ·0107 to ·0375 mm.; the larger ones have great persistence, and can be traced from pith out to the periphery.

The annual rings appear distinctly marked by a narrow white line without pores; they indicate a very slow growth, giving about 32 rings per inch of radius. The wood in this and other respects, such as character of the rays, recalls that of some Euphorbiaceous trees, *Buxus* among others. It also resembles, in some respects, recent

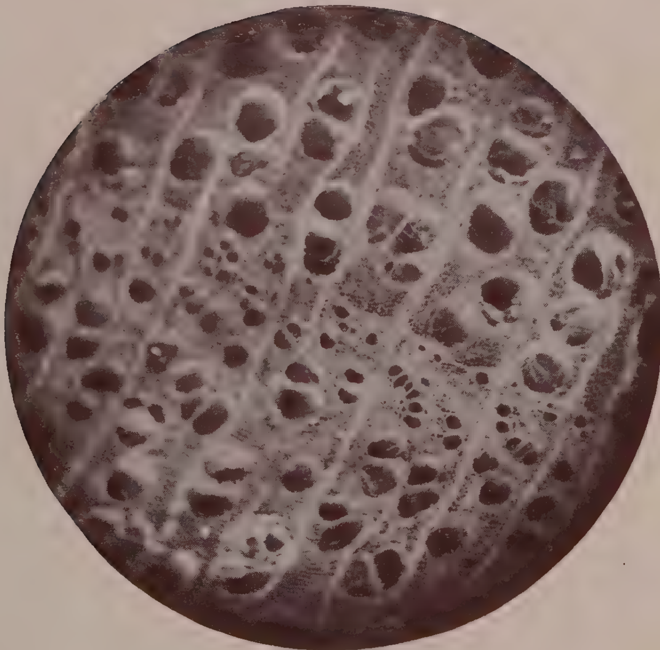


Fig. 3.

R. A. R., *Micrograph.*

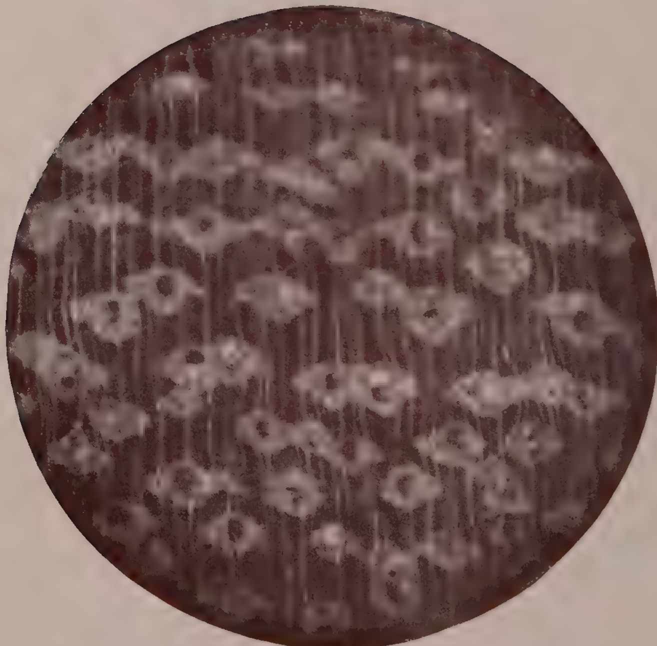


FIG. 2.

R. A. R., *Micrograph.*

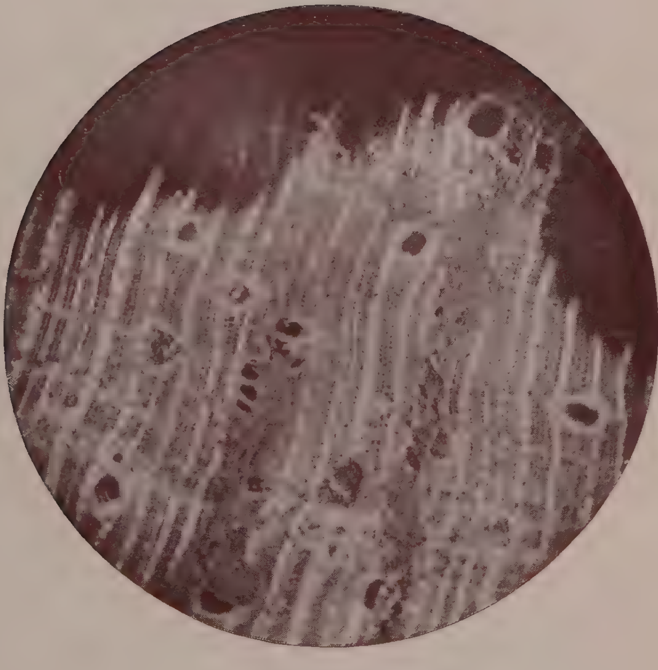


FIG. 1.

R. A. R., *Micrograph.*

tropical woods of the order Ilicineæ. On the whole, however, I am inclined to regard it as that of an evergreen tree allied to the Lauraceæ or Myristicaceæ.

Specimen 3, Plate II., is an irregularly triangular fragment, the outline of the cross section being a quadrant of the stem, the sides measuring approximately 65, 52, and 58 mm. The colour is a light brown, mottled with splashes of yellow and smoky black. Two-thirds of the fragment is in an indifferent state of preservation as far as the more minute anatomical structure is concerned, but the rays, rings, and tracheal apertures are perfectly evident all through. A drawing of a similar fragment, from Antigua, showing structure, is figured in Witham's "Fossil Plants." The annual rings are well marked. As to the growth of the tree, it would appear to have been moderately fast, there being about eight rings to the inch of radius.

The medullary rays are fine and of fairly uniform distribution, their breadth varying from ·0107 to ·0214 mm. They number about sixty-five for five millimetres tangential area. They bend outwards on either side of the tracheæ. These tracheæ are of approximately uniform size throughout and of extremely uniform distribution, they are scarcely appreciably more numerous towards the outer side of each annual ring; their average radial measurement is ·15, while the tangential is ·1178 mm.

They are commonly single, but radial groups of two are frequent, groups of three or more do occur, but rarely. Each large trachea is girdled by a ring of smaller elements which extend tangentially so as to connect neighbouring tracheæ and give rise to a series of interrupted false rings. The intervals between the rays vary in width from about the breadth of a broad ray to that of a large vessel, the average width being ·064 mm.

The structure of the general ground tissue can only be surmised, as its place is taken by translucent silica; possibly it consisted of a uniform matrix of fibres. The similarity of the transverse section to acacias of various species is striking, but these are faster growing trees with less numerous medullary rays. Its nearest recent allies are to be found among the Rhamnaceæ or Rutaceæ.

Specimen 4, Plate III., is, histologically, a rather interesting type. It is an irregular fragment of 3 cm. in thickness, and about 10 by 8 cm. in dimensions on the transverse polished face. Only a small part of this area, measuring 3 by 2 cm., however, exhibits structure, but the minute detail is very perfect. This particular part is distinguished by its dark brown ferruginous tint, as contrasted with the dark smoky tints merging into blue and grey of the bulk of the section. At first sight it would appear, from certain appearances in the cavities of the tracheæ, that at the time of silicification the fragment of wood was, to a large extent, far gone in decay, permeated by fungal hyphæ which have been fossilised *in situ* in the interior of the tracheæ. I am inclined to place a different interpretation on these peculiar appearances, but of this more anon.

The tree has been a deciduous one of moderate growth, about nine rings per inch of radius; the annual rings are very distinctly demarcated by the difference in calibre, as well as distribution of the various elements, as also by peculiarities of the medullary rays. These last are not very numerous, only about twenty-four on an average for five millimetres. Their breadth is fairly uniform, averaging ·0321 mm., except at the junction of each annual ring, when they broaden out laterally to twice or thrice their average in other parts of their course; even in the middle of a year's ring this lateral broadening may be remarked. In this peculiarity regarding the rays, it resembles some Leguminosæ as also Cupuliferæ. Their radial course is not very continuous; starting as a single row of cells, one may broaden out to the average extent, extend across a ring or little more, and suddenly disappear opposite a trachea, from the adjacent sides of which two new rays pass outwards. This eccentricity, of course, renders the interradial spaces of varied breadth; the interval between adjacent rays may be so great that there is room for two tangential rows of large tracheæ abreast; often, however, only one row, and frequently the spaces are so narrow that the rays are deflected outwards in passing tracheæ.

Annual Rings.—The average breadth is about 3·2 mm., and the annual rings are demarcated in the same way as in present-day trees. There is a highly porous zone

of spring wood with large vasa: the number as well as the size of the vasa decreases as the passage is made into the autumn wood. Here the tracheæ are very numerous, but of small size, and instead of occurring singly or in radial or oblique pairs or threes, they occur in little oblique tails or rosettes. While a spring trachea may measure ·1927 mm. by ·289 mm., those of the autumn wood average ·0214 mm. in diameter. Again, the fibre elements, forming the general wood matrix, also vary in size in the spring and autumn wood, the average diameter of one of these being, over all, about ·0153 mm.

In addition to what has been already given, the junction of the annual rings is marked by the lateral broadening out of the rays as already described.

The interior of many of the large vasa presents a peculiar appearance. Each appears to be filled with a network of irregular meshes, the threads of the mesh being of a different colour from that of the general mass. This might be due to some peculiarity of silicification, or to fungal hyphæ, or to thyloses. A careful and repeated examination of all the vasa leads me to think that the latter is the correct interpretation, and that the delicate threads are the preserved cell membranes of the thyloses parenchyma.

The resemblance in some respects to certain Cupuliferæ is fairly obvious; but in the number and breadth of rays, as well as the presence of thyloses, it resembles some Leguminosæ, such as *Robinia*, but in these respects also it has closer affinities with the woods of the order Meliaceæ, which are distinguished, however, by their somewhat more rapid growth.

EXPLANATION OF PLATES I., II., AND III.

Photomicrographs of opaque polished surfaces of the transverse sections of the stems, taken by the methods described in "Trans. Bot. Soc.," 1897.

NOTES ON THE WITCHES' BROOM OF PINUS SYLVESTRIS.

By A. W. BORTHWICK, B.Sc.

(Read 9th March 1899.)

Witches' brooms are bushy growths on trees which are induced by parasitic fungi. The fungus has a stimulating effect upon the growth, and as a result we find an excessive development of buds and twigs. The form of a witches' broom varies, the most common being the hanging clustered masses to be seen on many broad-leaved trees. The twigs in some cases are much elongated, in others shortened, but they never live long, and it is their rapid development and premature death which give rise to the tangled crow's-nest-like structure.

The characteristic features of a witches' broom are that, without regard to the direction of the branch on which it is borne, it is negatively geotropic in a marked degree, and that the point of infection is conspicuous as the starting-point of the broom. Shadebeck even regards any twig hypertrophy as a witches' broom.

Most witches' brooms are caused by an æcidium or an exoascus. They occur very abundantly on many broad-leaved trees, those of the cherry and birch being extremely common and familiar objects. Among the conifers we find them also, though not of such general occurrence as among the broad-leaved trees. Probably the most commonly known one is that induced by æcidium elatinum, on the silver fir; and, as far as I know, the least common one is that on our own Scotch pine. In the "Zeitschrift," edited by Dr. von Tubeuf, May 1898, p. 195, a photograph and a short account is given of a witches' broom on Weymouth's pine—*Pinus strobus.* In "Schlich," vol. iv. p. 395, it is stated that a witches' broom occurs on pines, but the fungus which causes it is as yet unknown.

Professor H. Mayr, of Munich, found this broom on pines in Japan; and he kindly informs me, in reply to a letter, that they are to be found here and there on spruce firs and pines, and that he even got them on cryptomeria, but they are exceedingly rare.

Last November I found a Scotch pine on which a witches' broom was growing. The tree was seventy years old and forty-five feet high, with diameter of one foot at breast height. It occurred in an old mixed plantation which occupied a steep slope with an eastern aspect. The condition of the wood may be described as distinctly open. The soil was light and sandy, with a covering of blaeberry and moss in some places. The part of the trunk from which the branch bearing the broom arose was seventeen feet above the ground, and showed forty-one annual rings, so that infection had occurred when the tree was forty-one years old. The broom itself was four feet long and three feet broad. It had a peculiarly dorsiventral structure, and all parts of it were extremely brittle. The needles, though numerous, were short, thin, and pale in colour, indicating a lack of chlorophyll. The average length of the needles of the same tree was two inches, while those on the broom averaged only 1·5 inch. All the needles of the broom were of this year's formation. This is somewhat similar to what we find in the broom of the silver fir, with this difference, that the needles of the abies broom are shed annually, while those of the pine broom persist till the year after their formation.

Some doubt exists as to whether this broom is caused by a fungus or an insect; but on examining the twigs microscopically, I found abundant traces of a mycelium in the wood and bast. I was able to trace the hyphæ to the base of the bud, but found no evidence of it in the bud itself, nor in the leaves. I have, therefore, come to the conclusion that in spring the mycelium grows on, keeping just behind the extending apex, and at the same time sending branches out into last year's needles, there to form its fructifications; and these needles being shed in summer or autumn, would leave nothing on the broom but this year's needles, which is the condition I found it in last November. As the tree has been cut down, there is no hope of making any further observations on this broom; but I am trying some artificial mycelium-infection experiments with a view to obtaining more material.

Botanical Notes of a tour in Upper Engadine and South-East Tyrol by three Fellows of the Edinburgh Botanical Society. By the Rev. George Gunn, M.A., Stichill Manse, Kelso.

(Read 13th April 1899.)

This paper has been communicated to the Edinburgh Botanical Society on the invitation of the Council. According to wise traditions, the Society wishes to be kept in touch with the botanical researches of its members in other lands. Though vouched by one signature, this paper has had the benefit of careful revision by W. B. Boyd, of Faldonside, and the Rev. David Paul, LL.D. Without their aid the writer would have been even more reluctant to undertake a botanical survey of the tour.

Reaching Munich on Thursday, 21st July 1898, we took a bee-line for the Botanic Gardens, which are prettily situated near the Crystal Palace.

As we were specially in search of Primulas, the gardener obligingly showed us his collection in the Rock Garden there. The critical specimens, unfortunately for us, had flowered some time before. He, however, gave us an opportunity not to be neglected of closely examining the foliage of *Primula pubescens*, Jacq.; *P. discolor*, Leyb.; *P. Muretiana*, Mor.; *P. Flœrkeana*, Schrad; *P. tirolensis*, Schott; *P. viscosa*, All.; and *P. œnensis*, Thom. (or *daonensis*, Leyb.); and other hybrids.

We put off no time at Innsbruck, where the Botanic Garden rather disappointed us, but where the fissured fronts of the mountains, towering above the town, sorely tempted us to visit them.

Steinach, on the Brenner Railway, was our next stopping place. It is a pleasant summer resort, situated among majestic mountains and picturesque ravines. Here the Sills is joined by the impetuous Gschnitz, up whose valley for three hours or more we were to walk. The choice is offered a pedestrian of a high road presenting beautiful views with the disadvantage of being sunny and dusty, or a footpath by the side of a river through moist meadows.

The hay of these alluvial pastures had just been cut, so there were comparatively few flowers to beguile our way. On a dyke were grand specimens of *Asplenium septentrionale* of lengthy and elegantly cut fronds. On the bank, near the same place, were found plants not unfamiliar to us: *Silene nutans*, L.; *Salvia pratensis*, L., with large bright blue flowers; the smaller *S. verticillata*, L.; the common *Lithospermum officinale*, L.; *Cuscuta Trifolii*, Bab.; and *Monotropa Hypopitys*, L. The orchids were more interesting. Best among them were clumps of a small pale yellow flowered one on thyme, which turned out to be the very rare *Epipogum Gmelini*, Rich.; others were *Gymnadenia Conopsea*, Br.; *G. odoratissima*, Rich.; *Neottia Nidus-avis*, L.; *Epipactis latifolia*, Sw.

Hurrying onwards, Trins, our half-way house of call, was reached in good time. This village nestles cosily at the foot of the Blaser Mountain. Between this and Gschnitz we observed large flowered *Diplotaxis tenuifolia*, L.; *Saponaria ocymoides*, L.; the dense *Saxifraga cæsia*, L.; *Pyrola uniflora*, L.; *P. chlorantha*, Sw.; the less rare *P. secunda*, L.; and *Globularia cordifolia*, L.

These and other flowers of greater or less rarity persuaded us to linger on the road. In a sunset of exceeding loveliness, views of lofty mountains outlined the horizon in matchless colouring, and most prominent amongst them were the Tribulaun, rising to 10,175 feet, and the Habicht to 10,760 feet. The small hamlet of Gschnitz is 4075 feet above the sea-level.

As it was towards evening, and as the keen air made us clamant for food, we hurried to the Herr Pfarrer's, who received paying guests,—quite a number of whom were taking wine with each other in a shed which had been erected for their convenience near his house. His housekeeper welcomed us with smiles, which grew broader from our failure to speak the language "understanded of the people." She spoke only Ladin, but was induced by the universal language of signs to provide us with food.

By way of interlude, may I take time to remind you that Ladin is said to be a corruption of many Romansch dialects. The late Dr. John Brown has recounted a tradition of its origin that I have not met with else-

where. He said that the great Creator sent angels with bags of languages to all peoples, who, on their return, rendered an account of their stewardship. To his pressing inquiry whether all the tribes had been supplied, it occurred suddenly to one angel that he had seen one tribe, brave in endurance, living among the snows and rocks of a lonely valley in the Tyrol, who had been unaccountably omitted. But there was no language left for them. One last resource was tried. On collecting the empty bags, they were all turned inside out and well shaken, when here and there words of all shapes and sizes, of all sounds and meanings, fell out into a goodly heap. An angel was commissioned anew, and instructed to convey this mixture of all languages to this corner of the mountains. Hence, while Ladin is like no one speech, it yet resembles them all.

This story has given time for the Herr Pfarrer to return from duty, and in a harsh German patois to promise us everything—beds for the night, a trusty guide, and grand weather for the morrow. Here a bit of ill-luck befell us. The most intelligent guide was accompanying Herr Porta, whose name is well known in connection with Primulas, in his botanical researches in these regions. What was left for us was a strapping, stolid youth, who cared nothing for flowers, was acquainted only with the frequented paths of the mountains, and spoke only Ladin—even more unintelligible when sounded through teeth closed on a heavy Tyrolese pipe, which, from 5 A.M. to 8 P.M., was only removed from his lips for the admission of sausage and brown bread and cognate et cæteras. However, and that was a lively satisfaction to at least one of the three, he undertook to return us safely to our quarters at nightfall.

So we started at 5 A.M. prompt for the Muttenjoch, which is a pass over the mountains separating Gschnitzthal from the Obernbergthal. Crossing the rushing Gschnitz, which was there not far from its glacial source, our way led along a mountain-side shaded with firs, larches, and pines, and carpeted with *Linnæa borealis*, L. Here and there in bushy places a dark form of an Aquilegia, possibly *Aquilegia atrata*, Koch, looked still darker in the gloom of its setting. Other interesting plants caught our gaze.

Every one was left severely alone in anticipation of richer spoil amongst the Primulas. The weary shoulder of the hill was at length rounded. Here, perched on a bold outjutting rock over 6000 feet high, were a church and monastery, in which old folks were interned while living, and round which their bodies were interred.

At last nearing the top of the Muttenjoch, we were fairly captivated by a glorious display of colouring. Here, for a half-mile or more in breadth, a web of Primulas wove their rosettes so densely that they took effective occupation of the place, and killed out the grass. The sunny air was redolent of their fragrance, and crowded with swarms of fluttering butterflies, bees, and ephemeral insects, hovering over the violet flowers, to the mutual advantage of insect and blossom. Close search amongst them was made, and we found that the vast sheet was mainly composed of *Primula glutinosa*, L., mixed with *P. minima*, L., with several intermediate forms between the two, such as *P. biflora*, *P. salisburgensis*, and *P. Flœrkeana*, Schrad. A few plants of *P. auricula*, L., and *P. farinosa*, L., were got a little lower down.

Our search for plants of this special genus precluded us from any systematic effort after other rarities. Still, the following, amongst other flowers, were often seen:—*Hutchinsia petræa*, Br.—rather frequent on these limestone hills; *Hedysarum obscurum*, L., with red instead of purple petals; *Saxifraga cæsia*, L.; *S. biflora*, All.; *S. aizoides aurantiaca*, L.; *S. aizoon*, L.; the ciliate-leafed *Rhododendron hirsutum*, L.—more prevalent here than the rusty-looking leaf of *R. ferrugineum*, L.; *Bellidiastrum Michellii*, Cass.; *Andromeda polifolia*, L.; *Androsace obtusifolia*, in sunny nooks; *Pyrola uniflora*, L., and *P. rotundifolia*, L., of large size; *Myosotis alpestris*, Schm'; the violet *Linaria alpina*, Rich.; and *Gymnadenia Conopsea*, Br.; with certain sedums and potentillas, and *Gentiana bavarica*, L.; and *G. verna*, L. In a high meadow were thriving plants of *Cystopteris alpina*, Link.; *C. montana*, Bernh.; and *Polypodium calcareum*, Sm.; tufts of crowberry, *Empetrum nigrum*, L.; the glistening evergreen bearberry, *Arctostaphylos Uva-Ursi*, Spreng.; and the trailing dark-green Azalea, *Loiseleuria procumbens*, Desv., clung close to the ground, as if in search of greater

warmth than can be had on the outstanding rocks and ledges.

Our return in the evening was something like a forced march, for Claus was hungry, if not athirst as well. One noticeable feature which we observed in our after-dinner stroll, was the extraordinary number of fireflies which flashed over the rapid water.

Having trysted Claus for next day, we started off at an hour unheard of in that late-slumbering valley, hoping to repeat upon Heimatkehl the splendid successes of our first day on the Tyrol. Neither Claus nor the Herr Pfarrer seemed sure of the whereabouts of this place, judging from their energetic and eloquent discussion, and the surprising vacillations of Claus's course. It turned out not to be a hill, but a very steep ravine, on its side densely covered with tall plants. Though we were striding over it in all directions, we could not discover a single hybrid Primula. Here and there, at long intervals, *Primula auricula*, L.; and *P. hirsuta*, All., were abundant, but not growing together, and therefore there was no *P. pubescens*, Jacq., which we specially desired to find. The feature of the neighbouring hill, from a botanist's point of view, was the vast display of *Arnica montana*, L.; *Gymnadenia odoratissima*, Rich.; *Mulgedium alpinum*, Less.; and *Carduus acaulis*, L. Claus had the luck to pick up a solitary *Orchis ustulata*, L. Another plant that redeemed the day for us was *Delphinium tirolense*, Kern., with dark blue sepals and petals. *Potentilla grandiflora*, L., made a brilliant show on the rocky ledges, with its large yellow blooms. Very gummy bushes of a lowly Salix contrasted beautifully with the two Rhododendrons. On the whole, Heimatkehl was a disappointing field—perhaps arising from the lateness of our raid into these southern parts. There were compensations, however. On all sides we enjoyed magnificent views of glacier upon glacier. The Habicht rose in snowy majesty at the head of the Thal, where Claus tried, and better tried, to show us the whereabouts of the Innsbrucker Hütte with the insistency of a silent man who had at last found something to say. The difficult Tribulaun ascended precipitously in front.

An after-dinner talk with the Herr Pfarrer brought this

excursion to a close, and an unlooked-for dole to his poor-box made clear that his English was limited to the expressive "Thank you!" We retraced our steps to Steinach that same evening.

The two days following were spent on the road to the Giudicaria Alps, farther to the south still. By train from Steinach we went over and down the Brenner Pass, through curved tunnels and along precipitous tracks, which zigzagged hundreds of feet perpendicularly above the line by which we were at last to come to the Brenner station and cross the watershed between the Adriatic and the Black Sea. Passing the commercial Botzen, we at length reached Trent, which was to be our headquarters, not from its ecclesiastical associations so much as from its convenience and accessibility to the Val Daone.

The heat was oppressive, and the shade of the Sumach, *Paulownia imperialis*, *Catalpa bignonioides*, and other graceful trees which lined the principal streets, was very grateful. Magnolias, palms, olives, etc., ornament the public gardens all the year round.

From Trent by carriage down the Val Sarca would have been a most enjoyable drive with a milder sun and a less dusty limestone in the air. Parched and baked as we were, this drive was the finest of many splendid excursions. The road shows marvellous engineering. By fatiguing zigzags it is carried over steep hills and down profound ravines, along tunnels and galleries overhanging the gorge of the tumultuous Sarca. The rocks were clad with *Dianthus Carthusianorum*, L., of vivid brilliance, which admirably picked out the yellow of the *Biscutella lævigata*, L., which grew in profusion there.

At last the Lago di Toblino was reached, where the darker olives imparted their tones to the pines and trees of the woods overhanging the shores. The heat and the dust contributed to our enjoyment of the Vino Santo of the castellan of Count Walkenstein. Still en route for Creto, for we were badly horsed, as the poor brutes had been evidently tired out before we started, we had to spend the night at Tione, the principal village in Upper Giudicaria. It lies at the confluence of the Arno and the Sarca. Bondo, Roncone, Lardaro, and Strada—little villages

prettily situated with old frescoes on the faded whitewash of their houses, and curious gratings to protect their windows, interesting wayside shrines, and Romanesque churches and imposing forts in the midst of grand scenery,—all were scenes which made the continuation of this drive of enduring charm. Our headquarters were at the Croce d'Oro at Creto or Pieve di Buona, almost the last village in Val Daone. Speaking her native dialect, the Italian landlady did her best to minister to our comforts. Though good of its kind, I have no doubt, to those who like it, the cooking, with so much garlic and oil, was not altogether palatable to our Scottish tastes. Through a chance visit of a German lady, the services of an English-speaking guide were secured for us. Frank Maestri had emigrated to Australia from this valley in his salad days, and had returned some years since with a modest competence. Investing his savings in a large house and croft, he became a great man in the little town, in which he gave us to understand that he had held various public offices with honour to the township and credit to himself. Unfortunately he cared little for Primulas. But he was a cheery and intelligent guide, and may be recommended to any botanist who desires to study the flora of that district.

Our walk to Stabolette lay for eight miles or so up the Val di Daone, down which the Chiesa Water coursed in mad turbulence for the Arno and the Adriatic. The cobble stones of the thousand feet of ascent between Creto and Daone caused exquisite torture, at the end of the day particularly, and knocked our feet to pieces; but these cobbles formed the drainage system of the district, and prevented the numerous rills of the rainy season rushing all the soil into the Chiesa. We were near the Italian frontier. Adamello, and other giants amongst the mountains, shone with a glistering whiteness in the morning sun. Our guide had no good to say of his Italian neighbours, whom he branded as greedy poachers for their wicked propensity to rob the edible frogs from the ponds of his township.

Little botany was done on the road, as the Primulas lay a long way ahead. Good plants were frequently in evidence. There were well-grown and strong plants of

Asplenium germanicum, Weiss.; while *Woodsia hyperborea*, R. Br., fringed the boulders; and *Struthiopteris germanica*, Willd., with fronds five feet long, on a low damp place at the foot of the wall. On the hillside, *Cyclamen europæum*, L.: *Anthericum Liliago*, L.; *Cephalanthera rubra*, Rich.; and mosses of wondrous luxuriance lined the stony path.

In the grassy ascent, in close proximity to the Alp hut, were the annual cowwheats, eyebrights, yellow rattles, and louseworts of light hues, which, by their extraordinary profusion, imparted brightness to the emerald green of the field.

Keeping to our rule, every other flower was secondary to Primulas. Here *Primula minima*, L.; *P. spectabilis*, Tratt.; *P. auricula*, L.; and *P. daonensis*, Leyb., or *œnensis*, Thom., were gathered, but only four plants of the last, after most diligent search,—perhaps because they were out of flower. The rare *Saxifraga Vandellii*, Sternb., was got near the summit. Upon a craggy knoll close by, the heads of the Edelweiss, *Leontopodium alpinum*, Cass., were expanded in sun-like stars of earth. There was also a distinct variety of a Pinguicula; but, as by ill-luck our specimens were left behind, we cannot speak positively of the species. It occurred nowhere else. Two forms of *Homogyne alpina*, Cass., one with a bronzed underside to the leaf, were frequent, as were also the two Soldanellas—*Soldanella alpina*, L., and *S. minima*, L.—and, of course, *Ranunculus glacialis*, L. *Daphne alpina*, L., was also found here.

The flowers on this Stabolette were similar to those of Stabolfresco, which we climbed on the Monday, after the refreshing rest of the Sunday at Creto. The morning walk along the valley was less pleasant; there was no shade, the air already was humid and oppressive, and not less so from the effluvium of goats that would keep close to us. The views of the long range of Monte Baldo were unspeakably grand. After a wearisome climb over wide uplands of meadow grass, we came on small plots of Primulas that had been long out of bloom, so that identification was difficult and doubtful, except in the case of *P. spectabilis*, Tratt.

Creeping along the lofty saddle-back, where *P. minima*, L., was in flower, and cautiously peering into precipitous

depths, from which rose a great eagle that may have been a Lämmergeier, we had ample recompense for our disappointment and toil. These limestone rocks, light and grey in colour, were streaked with lines of darker lichens with notable effect; indeed it looked as if their regular striation were due to some liquid dye oozing out of the rocks. In the bogs were orchids which have been named before. *Gentiana lutea*, L., was plentiful, to the delight of Frank, who liked to munch its astringent root. *Soldanella alpina*, L.; *S. minima*, L.; *Aster alpinus*, L.; *Loiseleuria procumbens*, Desv.; and *Draba aizoides*, L., the same which is found at Pennard Castle, and Worm's Head in Glamorgan, were usually abundant, as were *Ranunculus glacialis*, L., and the Edelweiss.

Frank took the way home right across country, and treated the steep outlying spurs of the mountains as mere steeplechase fences. However, on sub-Alpine steeps, where the hay harvesters were tied to stakes and wore clamps, *Epipactis latifolia*, L.; *Orchis pyramidalis*, L.; *Cephalanthera ensifolia*, Rich.; *C. rubra*, Rich.; *Epipactis rubiginosa*, Crutz.; and *Orchis ustulata*, L., were growing to luxuriant size.

Frank Maestri's outspoken revelations of the superstitions and habits of his stay-at-home countrymen, and his dislike of the priests, were rather diverting. He also showed us some ores of lead and hæmatite, and offered to exchange his knowledge of the whereabouts of a rich mine with a British syndicate for a modest douceur.

He was up with the lark next morning to start us pleasantly for Trent. Thence by train to Meran, and from there, in two days of long drives, to Nanders, and then Samaden. So we came to Pontresina, our headquarters in the Upper Engadine.

The grand view of this route was the Ortler group of mountains. Their scarred and embattled fronts outlined the horizon, and the jagged-pointed pyramid of the Ortler itself seemed to pierce the very heavens.

It was at once evident that we had passed from the limestone of the Giudicaria range to the gneiss and granites of the Upper Engadine. The scenery of the Lower Engadine is less attractive to those who have

feasted their eyes on the grander sights above Samaden; although, by the way, above and below Samaden for a short distance the character of the landscape is less striking. For although the river Inn runs through it, it no longer presents its former picturesqueness. Straight symmetrical banks confine its straying waters, and give it the appearance of a mathematical canal. The valley of the Berninabach, which flows past Pontresina in the Upper Engadine, is very narrow. It is hemmed in by lofty mountains, and offers close views of attractive glaciers and snowy peaks. The Bernina group of mountains close it at one end, and the Inn, flowing from the lakes of San Moritz, Silvaplana, and Sils, at the Samaden end.

We could attempt the study of the botany of this wide area only in a fragmentary way. We chose that of the meadows and woods, and of the mountains of easy access. The dark woods around Pontresina, with the Heuthal or Val del Fain, may stand for the one, and the Piz Languard, with the shoulder of the Bernina and the Morteratsch glacier, will do for the other.

The Heuthal or Val del Fain is a valley about five miles from Pontresina, at an altitude of over 6000 feet, and is about five miles long. We walked up to the head of the valley, and returned on one of the ridges. Every step was of entrancing interest to a botanist. This valley was an inexhaustible treasure-house of flowers rare and flowers common; of flowers of every conceivable colour—white and red, blue and yellow—in fine contrast to the cream and grey-coloured rocks and the green of the grassy slopes.

Of the many Campanulas the more interesting was *Campanula thyrsoides*, C., whose crowded spike was prominent at the side of the path, and was more difficult to dig out than *C. barbata*, L.; or *C. pusilla*, Hænk., which were very common. *Phyteuma orbiculare*, L., was widely spread amongst the rather infrequent *P. hemisphericum*, L., and *P. humile*, Schleich. *Lloydia serotina*, Richl., showed its milk-white fragile flower in close company with *Nigritella angustifolia*, L., *Helianthemum canum*, L., *Lilium Martagon*, L., *Anthericum ramosum*, L., *Saxifraga cæsia*, L., *Silene acaulis*, L. (pink and white varieties), and many orchids,

some of which seemed more like hybrids than typical plants. The Edelweiss must not be omitted.

On the side of the roads, or amongst the woods that clothed the slopes of the mountains and led to San Moritz, were large patches of *Eriophorum alpinum*, L., side by side with bog-loving plants belonging to the *Carex, Juncus*, and *Luzula* genera. *Linnæa borealis*, L., was in luxuriance at the foot of tall firs which looked darker than they were really, from the confused festoons of *Usnea barbata*, of grotesque hoariness. *Lonicera alpina*, L., grew in a gully frequented by chamois, which we had the fortune to see at close quarters, and *L. nigra*, L., adorned some of the trees. We made the acquaintance also of the high-growing dwarf *Pinus mughus*, Scop.

Some trees, such as the Arctic Willows and the Arolla Pine, were conspicuous, and though now apparently indigenous, are not really so. They hail from Siberia. Sir John Lubbock informs us that they could not, under existing circumstances, cross the intervening plains, but must have occupied them when the climate was colder, and afterwards been driven up into the mountains, like the marmot and the chamois, as the temperature rose.

Here also, on rocky crevices, were Primulas which had flowered, but which were easily identified as *Primula viscosa*, All.; *P. hirsuta*, All.; and *P. integrifolia*, L.; and in the meadows were *P. farinosa*, L.

The Alpine flora of this neighbourhood, as seen by us, was confined to our excursions to the Piz Languard and the shoulders of the Bernina range.

The Bernina Hospice lies four miles farther along from the Bernina Houses, which mark the entrance to the Heuthal. On the way we get beyond the zone of trees. Some twenty-two scarred, ragged, lop-sided firs show the sharp severity of the weather they have to face. Another evidence of the winter there is seen in a black line on the third storey of the hospice, which marks the depth of the snowfall one recent winter. The elevation of the hospice is 7575 feet. It is magnificently situated, almost overhanging two glaciers and the four lakelets which form the watershed. Lake Nero, which is the upper one, often in rainy weather overflows at both ends; if northwards, its waters form the

Berninabach, a tributary of the Inn, which ultimately falls into the Black Sea; and if southwards, into the lower Lake Bianco, whose waters are carried off by the Adda, which, by way of Poschiavo, reaches the Adriatic. The surrounding mountains are crowned by the lofty Piz Bernina, and all round there opens a noble amphitheatre of surpassing grandeur. We did not attempt to go far up this mountain. The flowers we met with were chiefly those of the Piz Languard, which rises to 10,715 feet, and up which we painfully plodded our weary way one hot morning.

The road is well marked, cannot be mistaken except after snow has fallen, and offers no difficulty other than that of the strain of a long climb. The pathway at first leads through a wooded promenade, and chief among the trees were noble larches and pines, from the lofty *Pinus Cembra*, L.; *P. sylvestris*, L.; to *P. Pumilio*, Hænk. The violet flowers of the large *Phyteuma Halleri*, All.; and the less showy *P. Scheuchzeri*, All.; *Campanula barbata*, L.; and various Umbellifers, made the stepping of varied interest. The leaves of *Anemone nemorosa*, L.; and *A. Narcissiflora*, L.: *A. alpina*, L.; and *A. baldensis*, L., were seen here and there. The sombre *Bartsia alpina*, L.; a very long Bupleurum—*Bupleurum falcatum*, L.; *B. stellatum*, L.; and perhaps *B. rotundifolium*, L., were gathered.

On higher ground, clumps of *Linaria alpina*, Mill., and a second form with violet flowers also, in which the yellow throat was absent. There were various Veronicas and small Composites. On a cliff near the top, the woolly dark blue *Eritrichium nanum*, Schrad., was a welcome sight, as well as *Androsace Chamæjasme*, Host., with its white flowers starring the rocky ledge, with here and there a red *A. glacialis*, Hoppe.

Here, as on the Bernina, the plants of *Ranunculus glacialis*, L., were mostly of a red colour, and mayhap were *R. roseus*, Heg. The Gentians here embraced *Gentiana cruciata*, L.; *G. campestris*, L.; *G. acaulis*, L.; *G. verna*, L.; *G. brachyphylla*, L.; and *G. bavarica*, L. At the top of the Bernina Pass were got *Primula Berninæ*, Kern.; *P. Dinyana*, Lag.; and *P. Muretiana*, Mor. At the far end of the lakes, near the Bernina Hospice, *Eriophorum*

Scheuchzeri, Hoppe, with its handsome globular heads, was abundant.

Our journeying was now homewards. From the Engadine to Chur, along the Albula Pass, was a long drive of nearly fifty miles through scenery so rugged as to baffle my power of description, and along rich fertile meadows of lovely quiet pastoral beauty. In the wood through which the road climbed with seven long bends, *Nigritella angustifolia*, Rich., formed an uncommon display. The roadsides were bright with *Campanula pusilla*, Hænk., both white and blue, and *Linaria alpina*, L., and variously coloured *Gentiana campestris*, L., and amidst a great debâcle of riven rocks, while our horses were eating loaves of brown bread, were gathered *Primula viscosa*, All.; *P. integrifolia*, L.; along with the hybrids, *P. Muretiana*, Mor., and *P. Dinyana*, Lag.

The evening shades were falling fast before the tired horses were driven into Chur. Here these reminiscences of our hunt for Primulas must end. With an earlier start, our record would probably have been richer. Enough has been said, perhaps more than enough but for your courtesy and patience, to point to the exceeding luxuriance of the Alpine and sub-Alpine floras of the Upper Engadine and South-East Tyrol. Each of these districts possesses a flora of its own, and of a distinct character, yet they also are enriched with identical plants which have found a home in these far distant districts where, perhaps, they were not originally indigenous. Naturally, the floras of our tour were more closely related to each other than to the Alpine flora of our own country. At first one looks to find the same species, and perhaps the self-same flowers on every beetling crag of an equal level above the sea, or in all humid corries or dark rocky fissures or stony wastes on a mountainside. But the geographical botanist records other agents that have influenced the distribution of plants, and shows that, in the nature of things, Alpine plants must vary according to their habitats, the prevailing climate, the distance from the sea, the nature of rocks and soil, and so forth. Centres of distribution of plant life there have doubtless always been, but many plants have now become naturalised that are not native to the spots in which they

occur to-day. There are few, comparatively speaking, of these travelled strangers from the Southern Alps which have found a home for themselves on our British Alpine heights. But one feature all possess in common: they offer an ample tribute to every admirer. These tiny gems that burst into rich and varied life at the confines of perpetual snow, whether at home or abroad, whether common or rare, are amongst the influences that are most beneficial to men and women awearied with the trammels of life. As their delicious fragrance hovers in the air we breathe for the moment, as their exquisite pencillings in colours and design and graceful inter-twinings hold captive our imagination even for a brief spell, and as their associations and symbolisms bring home to us the truths they are for ever telling in their frailty, they encourage us to take up our life afresh and make the best of it, even in harsh and unlovely surroundings, and so give back joy and confidence and companionship to those who look upon us and the life we live.

> "One impulse from a vernal wood
> May teach you more of man,
> Of moral evil and of good,
> Than all the sages can."

OBSERVATIONS ON THE GERMINATION OF THE SEEDS OF CRINUM MACOWANI, BAKER. By JOHN H. WILSON, D.Sc., F.R.S.E. (With Plate.)

(Read 13th April 1899.)

CRINUM MACOWANI was first described by Baker, in the "Gardener's Chronicle," 1878, vol. ix. p. 298, from living specimens which had been grown for several years in the Palm House at Kew, and from dried specimens sent from Cape Colony by Prof. MacOwan. Its close relationship with the Cape species, *C. Moorei*, and the Asiatic one, *C. latifolium*, is referred to by Baker, in "Flora Capensis," vol. vi. p. 202. The remarkable structure of the seeds of the genus has been long known to botanists.[1]

[1] See Lubbock, On Seedlings, vol. ii. p. 595.

The plants which afforded material for the present study (at St. Andrews) attained the large proportions indicated in descriptions of the species. When in flower they form stately objects in a roomy conservatory.

The long neck of the bulb (Fig. 19*n*) is a noteworthy character. On one occasion bulbs in pots were laid almost horizontally under a stage in a greenhouse in winter, the young leaves forming the neck being then enclosed in the dry membranous basal parts of older leaves. When in that position the necks curved upwards, and exhibited, by reason of their massiveness, a rather striking illustration of negative geotropism.

Fertilisation of the flower is readily accomplished by hand. The ovaries (Fig. 1*ov*) swell with considerable rapidity. The fruit (Fig. 2) is sometimes reddish, but is commonly a dull greyish green. All the examples under examination were found to be solid bodies, each composed of a single seed, roughly hemispherical in form, and about $1\frac{1}{2}$ inch in diameter. The mass of the seed is composed of a firm, fleshy, moist endosperm, containing a very considerable number of chlorophyll granules. The large, elongated, somewhat curved embryo (Fig. 4*em*) lies embedded in the endosperm.

If seeds be left for a few weeks, even on so dry a place as a shelf, they will germinate. The radicle makes its appearance as a stout peg (Fig. 3*r*), but at no determinate point of the seed. It is stated by Herbert[1] that the germination of *Crinum* seeds can be expedited "by cutting carefully off a portion of the fleshy mass, so as to expose the point of the embryo"; and, further, that "the operation requires a cautious hand, for if the point is cut by the knife, the vitality of the seed is destroyed."

In the first experiment, a seed was kept in a desk until the cotyledonary process, terminated by the radicle, had protruded $\frac{1}{8}$ inch (Fig. 3). The seed was then dissected, so as to expose the embryo longitudinally, but still leave it adherent by one side to the endosperm (Fig. 4). The part cut off was replaced, and the whole then bound together and laid half-sunk in the soil, the radicle being

[1] Herbert, Amaryllidaceæ, p. 402.

directed upwards. When kept in this position for two winter months in a temperate greenhouse, the cotyledon grew 1 inch, and curved geotropically over the seed, until the greenish yellow tip almost touched the surface of the soil. In another four weeks it widened vertically to some extent, and grew another $\frac{1}{4}$ inch in length, but did not penetrate the soil. The ligatures were then removed, and the entire embryo was found to be fresh. The experiment was carried no further; enough, however, had been done to show the great vitality of the embryo, and to suggest the possibilities of using this seed in a variety of experiments, to demonstrate phenomena associated with germination and embryonic life.

Another seed was allowed to germinate as it lay on a shelf, until it produced a bent cotyledon about 1 inch in length. The seed was then placed on damp moss in a pot in a greenhouse, but in a new position, so that the direction of the growing organ was changed. After a time the seed was again turned, and growth in a new direction thereby induced. The repeated efforts on the part of the cotyledon, in response to geotropic force, resulted in a curious twisting of the stalk or petiole (Fig. 5). Meanwhile, great swelling at the tip of the cotyledon, due to the development of the young bulb (Fig. 5*b*), and a corresponding shrinkage of the seed, caused by the removal of formative material, had occurred. The bulb commences to develop close to the apex of the cotyledon. The radicle elongates at the actual apex, to become the primary root (Fig. 5*pr*). As the bulb enlarges, the part of the cotyledon around it expands and constitutes the first tunic. Behind the expansion, the stalk of the cotyledon is solid, with vascular bundles passing through it longitudinally. The seed in question was left lying on the moss for another month, and during that time the bulb increased in diameter from $\frac{5}{16}$ to $\frac{7}{16}$ inch, and the cotyledon sheathing it had begun to split in the widest part (Fig. 6*s*). The primary root had made no further growth.

In the course of another six weeks, the seed (still lying on the moss) had visibly diminished in size, and the growing bulb (Fig. 7), now $\frac{3}{5}$ inch in diameter, had

ruptured the cotyledon so far as to expose about half of the outermost leaf-tunic. The connecting stalk of the cotyledon was still fairly fresh.

A further period of about six weeks elapsed before the next observation was made. The seed had now a collapsed appearance (Fig. 8), and the cotyledon was withered, brown, and spirally twisted. The part of it forming the sheath around the base of the bulb was still green. The apex of the second leaf-tunic was held in the split stalk of the cotyledon, but a very slight untwisting liberated it. The primary root had remained undeveloped.

In another fortnight the cotyledon had become so fragile that, for the first time, it could not bear the weight of the bulb when the whole structure was lifted up (Fig. 8). Some indications of the development of adventitious roots around the aborted primary one were now discernible. In another three weeks, now 7th April, the bulb seemed to have become almost dormant (Fig. 9). The adventitious roots, however, were now more visible, as four small protuberances in the persisting portion of the cotyledon (Fig. 10*ar*).

The final observation, made two months later, on 7th June, showed that growth was now going on (Fig. 11). The four roots, the longest being $\frac{1}{2}$ inch, had penetrated the moss, and a fifth was just appearing. A fairly vigorous green leaf was shooting up, its apex being nearly three inches above the base of the bulb. The persisting shield-shaped portion of the cotyledon was now papery, with the exception of a green piece, $\frac{1}{8}$ inch wide, close to the roots. The bulb was of fine healthy green colour, and would have grown well if it had now been transferred to soil. It is probable that it owed some of its vigour to the decay of the moss in which the roots were spreading.

The interesting feature of this experiment was the demonstration of the transference of stored material from the fleshy endosperm of the seed to the equally fleshy tunics of the bulb, with no more extraneous aid than that which accrued from the absorption of a little moisture by the bulb.

A third seed was dealt with otherwise. It was laid on its flat side on the earth, and allowed to germinate until its radicle had grown straight downwards $\frac{3}{8}$ inch. It was then turned upside down, and in a few weeks the cotyledon bent itself completely over, that is through an angle of 180°, until the apex pressed a little against the surface of the seed. The arch thus formed leaned a little to one side (Fig. 12), and growth continued until, in the course of another month, 10th December, the apex had slid forward and entered a hollow of the seed and become fixed. The point was now released by pressing it to one side, so as to allow it to develop without restraint (Fig. 13). The cotyledon now grew straight downwards, and the apex penetrated a short distance into the soil. In twelve weeks, 3rd March, the young bulb had developed and grown considerably, being now $\frac{7}{16}$ inch in diameter, and the radicle had elongated as a stout primary root $\frac{1}{4}$ inch long (Fig. 14). It soon became evident that the root action materially supplemented that of the cotyledon in furnishing nutriment to the growing bulb, its growth being much more rapid than that of the example described above, in which the root was undeveloped. In the course of another seven weeks, 24th April, the bulb (Fig. 15) measured $\frac{13}{16}$ inch diameter, and the primary root, $1\frac{1}{8}$ inch in length. By this time two adventitious roots had grown considerably (Fig. 15*ar*), while the greatly expanded sheath of the cotyledon, intact elsewhere, had been ruptured above by the growing leaves (Fig. 15*l*). The stalk of the cotyledon was still fairly fresh, but the seed had shrunk greatly.

After a further interval of six weeks, the bulb (Fig. 16) had added only $\frac{1}{16}$ inch to its diameter, but great growth in both leaf and root had taken place. The primary root (Fig. 16*pr*) was now $2\frac{3}{8}$ inches long, and of three adventitious roots produced, one was rather longer than the primary root, and the other two shorter. Well-developed leaves were also present, the largest being $\frac{1}{2}$ inch wide. The sheath of the cotyledon still enclosed the bulb completely, as a light brown, scarious, veined tunic. The stalk was quite withered, but still strong enough to bear the weight when the young plant was suspended by it. The seed

was very much contracted and wrinkled. This example, no doubt, showed the normal development of the seedling.

A fourth seed was allowed to produce a cotyledon $\frac{1}{2}$ inch long, which was then broken off close to the point of exit (Fig. 17*c*), and the seed placed in a pot, with the broken part in contact with the soil. No visible change took place for at least four months. After five months it was noticed that a very slight growth had recommenced, the broken part being now warty; and in another month the broken part was $\frac{1}{4}$ inch across (Fig. 18), and protruded at one point $\frac{1}{6}$ inch above the surface of the seed. The seed itself was as firm and fresh as ever.

Explanation of figures in Plate. (All the figures, with the exception of Fig. 19, are of natural size.)

1. Fertilised ovule, *ov*, on pedicel; *p*, faded perianth.
2. Fully developed single-seeded fruit on pedicel.
3. Germinating seed—*h*, hilum; *r*, radicle.
4. The same dissected—*em*, embryo; *en*, endosperm.
5. Another seed—*c*, point of exit of cotyledon (radicle); *b*. young bulb; *pr*, primary root.
6. Bulb of above at later stage—*s*, split of cotyledonary sheath.
7. Still late stage of the same—*pr*, primary root; *cs*, cotyledonary sheath.
8. More advanced stage of the same—*pt*, petiole of cotyledon.
9. Bulb free from the seed—*cs*, sheath of cotyledon.
10. Basal portion of sheath—*ar*, adventitious roots appearing as protuberances.
11. Young bulb growing—*cs*, remains of cotyledonary sheath; *ar*, adventitious roots.
12. A third seed germinating—*pt*, petiole of cotyledon.
13. The same at a later stage.
14. Bulb of the same, later—*pr*, primary root.
15. The same, with leaf breaking through the cotyledon—*l*, leaf.
16. Seedling well advanced—*pr*, primary root; *ar*, adventitious root.
17. A fourth seed—*c*, broken part of cotyledon.
18. The broken part of the cotyledon at a later stage.
19. Old plant—*n*, neck; *o*, offsets.

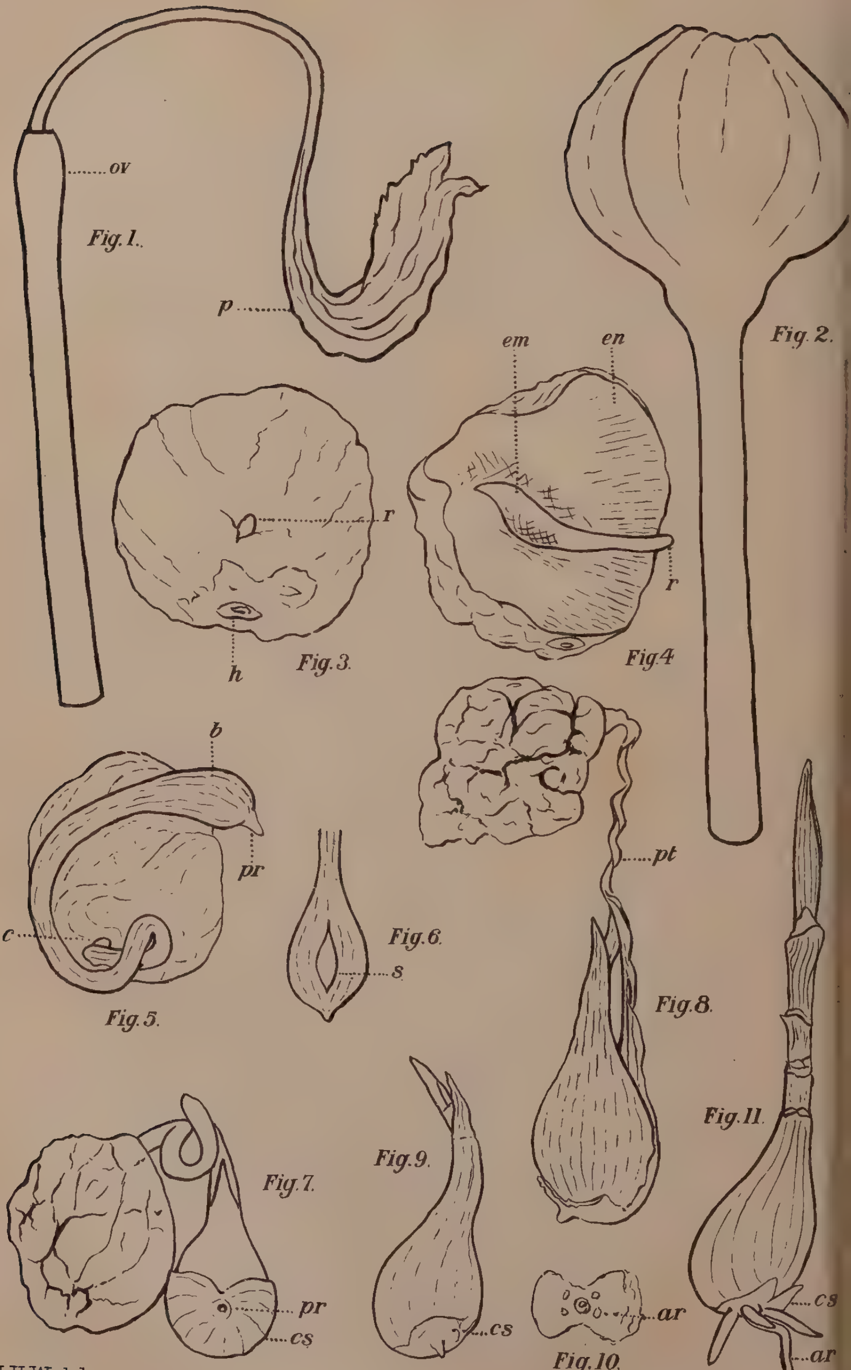

ov
Fig. 1.
p
Fig. 2.
em
en
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Fig. 3.
Fig. 4
b
pr
c
Fig. 5.
Fig. 6.
s
pt
Fig. 8.
Fig. 11.
Fig. 7.
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Fig. 10.
cs
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Fig. 12.

Fig. 13.

Fig. 14.

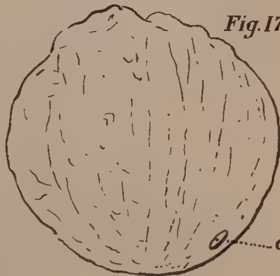


Fig. 17.

Fig. 18.

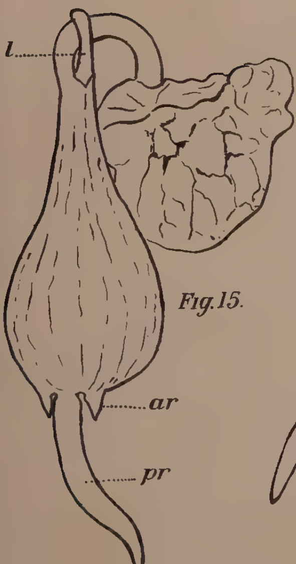


Fig. 15.

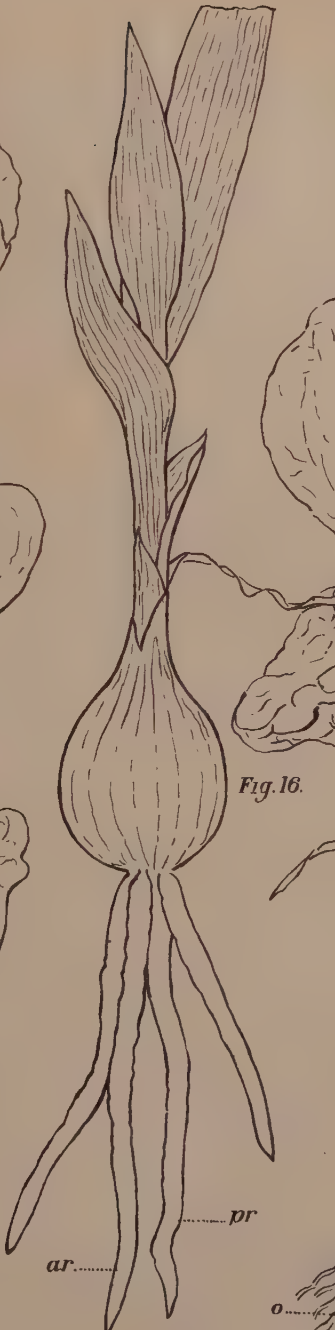


Fig. 16.

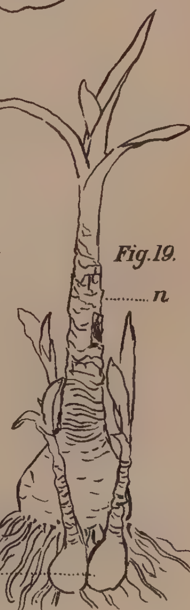


Fig. 19.

Note on the Discovery of Gentiana nivalis, Linn., in Sutherlandshire. By John Lowe, M.D., F.R.S.E.

(Read 13th April 1899.)

In 1896, I found *Gentiana nivalis*, Linn., on Loch Assynt, on some rocks near Ardvreck Castle. It was in considerable quantity, and some growing near the edge of the water. I have never before found it growing at the sea-level in Scotland, though it comes very low down in Norway.

Dryas Octopetala was also very abundant.

Note on the Occurrence of Ascoidea rubescens, Bref., in Scotland. By James A. Terras, B.Sc.

(Read 11th May 1899.)

This fungus appears to be not uncommon in Germany, where it was discovered by Brefeld growing on the fluid which runs down the stem of beech trees affected with the disease known as "Schleimfluss"; but, so far as I am at present aware, it has not hitherto been recorded from Scotland.

The first specimens which I examined were from a distillery in the north of Scotland, and were found growing in an earthenware pipe through which overflow water from the tanks in which the barley is steeped before malting was constantly flowing in small quantities, though a very much larger volume of fluid must of necessity pass over the plants whenever the tanks are discharged, an operation which takes place at short intervals.

The fungus was particularly abundant at the free end of the pipe, where it opens into a collecting tank at some little height above the level of the water; and growing in this somewhat peculiar position, the plants appeared perfectly healthy, but showed no signs of either sporangia or conidia, though both forms of fruit were afterwards obtained in abundance by means of artificial cultivation on gelatine and agar plates, as well as in gelatine tubes.

I have since found the same plant growing in considerable quantity in and about another distillery at some distance from the first; and it is possible that the specimens taken from the pipe in the first instance may have been merely washed down by the steep water from a more congenial situation, though this I am not yet in a position to prove.

It is worthy of remark that neither of the distilleries in question is in the habit of using either foreign barley or foreign yeast, so that introduction of the fungus by this means appears to be excluded from consideration.

THE FOLLOWING EXHIBITS WERE SHOWN AT THE MEETING ON THURSDAY, 11TH MAY 1899. By Professor SCOTT ELLIOT, M.A., B.Sc., F.L.S., F.R.G.S.

A collection of Spanish flowering plants obtained in March of this year in Andalusia, all from a small district at the exact boundary of the alluvial valley of the Guadalquivir and the foothills of the Sierra. The associations studied were—

I. RIVERSIDE ON THE SIERRA.—This was characterised by a rich profusion of Selaginella and Adiantum; many creepers, such as Bryonia, Tamus, *Smilax asper*, Aristolochia, and Clematis. Tamarisk and Ficus were amongst the trees.

II. THE SIERRA ITSELF.—This was remarkable for the Palmetto scrub, Thymus, *Notochlæna lanuginosa*, bulbous plants, etc. In small basins of tertiary age in the primitive rock of the Sierra were found Rosemary, an enormous white Cistus, and other shrubs.

III. UNCULTIVATED ALLUVIAL PLAIN.—This was covered by woods of *Quercus ilex*, with an undergrowth of a small white Cistus, etc.; *Lavandula stœchas*; *Ornithogalum umbellatum* in damp places.

IV. CULTIVATED ALLUVIUM.—A fallow field was covered by Leucojum, and many British plants were found in the waste ground, such as Borago, Anchusa, Reseda, Cynoglossum, Symphytum, Scrophularia, and also Calendula.

A collection of mosses, including three species of Andræa; *Oligotrichum hercynicum*, Ehrh.; *Hedwigia ciliata*, Dicks.; and four species of Hylocomium, all in good fruit. By Mr. John R. Lee.

Some rare and interesting fungi, including *Dædalea unicolor*, Fr. (on beech logs, Bishopbriggs), not apparently found before in the west of Scotland. From Mr. J. Wylie.

Polyporus brumalis, Fr.; *P. picipes*, Fr.; *Thelephora laciniata*, Pers.; *Hydnum zonatum*, Balsch.; *H. compactum*, Pers.; *Corticium cæruleum*, Fr.; and others. From Mr. W. Stewart.

Specimens of Silver Fir attacked by *Sirex gigas* and *S. puniceus*, with specimens of the insect, larva, and pupa. From Mr. Ballantyne, Rothesay.

Specimens of timber from North America, with larva and pupa of a beetle, apparently *Asemium mæstum*, Haldeman. From Mr. James Ferguson.

Professor Scott Elliot, on behalf of the Natural History Sub-Committee of the British Association Meeting in Glasgow, 1901, also gave an account of what the Botanical section are attempting. A complete list of the Flora of the Clyde district is the aim which they have in view. Information is specially desired as to—(1) Distribution of Species; (2) Papers in Magazines, Journals, and Transactions of Societies, which might otherwise be overlooked; (3) Names of workers in the different departments who might be willing to assist; (4) Information as to Herbaria or collections of dried plants; (5) Collections of microscope slides of botanical interest.

The maximum area, as arranged by the Committee, to be overtaken is "the natural drainage area of the Clyde, and of all the sea lochs which form extensions of its estuary." The northern limit, therefore, is the watershed beyond the head of Loch Fyne; and the southern boundary has been defined as a line drawn between the Mull of Cantire and the most southerly point of Ayrshire.

A leaflet has been prepared, showing the names of the different compilers, which will be forwarded to those willing to assist, on application to him at 204 George Street, Glasgow.

Obituary Notice of the late Malcolm Dunn, V.M.H. By Robert Lindsay.

(Read 8th June 1899.)

We have to deplore the loss of Mr. Malcolm Dunn, gardener to the Duke of Buccleuch at Dalkeith Palace Gardens, who died there suddenly and unexpectedly on the 11th of May last, at the age of sixty-one years. His death removes from among us one of the most prominent, conscientious, and energetic members of this and kindred societies.

Mr. Dunn was born in the parish of Methven. Perthshire, and received his early education at the parish school, Crieff. He served his apprenticeship as a gardener in Strathallan Gardens, Perthshire. Subsequently he was employed in several of the best private gardens in England. In 1865 he was appointed head gardener to Lord Powerscourt, at Powerscourt, Co. Wicklow, Ireland. Here he became widely known by the successful manner in which he combated the *Phylloxera vastatrix* in the vineries at Powerscourt. At that period the dreaded "vine disease" threatened to overrun this country, as it had done in France, and his method of submersion proved most efficacious in staying its ravages. After a stay of six years in Ireland, Mr. Dunn was engaged by the Duke of Buccleuch as head gardener at Dalkeith Palace Gardens in 1871, and how he maintained that establishment up to its former high level is well known.

As a gardener he excelled in most branches of his profession, but he was best known as a pomologist. He had an intimate and most extensive knowledge of varieties of fruit trees, and he took a prominent part in the promotion of the several Fruit Conferences of the last twenty-five years.

Mr. Dunn became a member of the Botanical Society in 1870, and frequently served on the Council. He contributed largely to the success of our meetings, both by interesting communications and exhibitions of rare plants, and was ever eager to give his aid in all matters connected with this Society. So late as March last, in his usual health and vigour, he exhibited a number of specimens of flowering trees and shrubs at our meeting.

Mr. Dunn led a very busy life. A society in which he was specially interested, and in which he was a leading spirit, was the Royal Scottish Arboricultural Society, which he joined in 1868. In recognition of the extraordinary value of his services to that Society, he was unanimously elected an honorary member last year. The Royal Caledonian Horticultural Society, which he joined in 1871, owes much to the energetic activity of Mr. Dunn. In 1886 he was awarded by the Council of that Society the Neill prize, in recognition of his services as a distinguished Scottish gardener. He took a leading part in the Apple and Pear Congress promoted by the Royal Caledonian Horticultural Society, held in Edinburgh in 1885, as also the Plum Congress, held in 1889; and he edited the valuable Report of both Congresses, embodying the results of their labours.

So late as last year, he exerted himself, with his characteristic energy, in obtaining a new Royal Charter for this Society, to enable it to do better work, with the result that this has now been obtained.

The Scottish Horticultural Association, of which he was one of the originators, was founded in 1877, and during its infancy was piloted by Mr. Dunn. He was President of the Association for the first five years in succession. His labours on their behalf were recognised by his being made an honorary life member.

To the Conifer Congress, held at Chiswick in 1891, Mr. Dunn lent unwearied aid, and his exertions were much appreciated.

The Veitch Memorial Medal was awarded to him in 1896, and he was awarded by the Royal Horticultural Society of London the Victoria Medal of Honour in 1897.

Mr. Dunn took a very warm interest in the Gardeners' Royal Benevolent Institution, of which he was a member since 1872. The Gardeners' Orphan Fund, and other garden charities, never appealed to him in vain. Indeed, his extreme willingness to assist every deserving cause was remarkable. He was always ready to help and advise others, and many a gardener throughout the country will mourn his loss. He was one of the most unselfish of men.

In concluding this brief notice of our departed friend,

I may be permitted to say that I rejoice to know that steps are being taken by the various societies with which he was so long and honourably connected, to raise some fitting memorial to commemorate this distinguished and worthy man.

Obituary Notice of the late Dr. George C. Wallich. By The President.

(Read 13th July 1899.)

By the death of Surgeon-Major Wallich, the Botanical Society of Edinburgh has lost one of its original members, and, so far as I know, he was the last survivor, with the exception of Dr. R. C. Alexander-Prior, M.D., F.L.S.

The first meeting of our Society was on the 17th March 1836, and the members present were—Drs. Grahame, Greville, Neill, Balfour, Barry, Parnell, and Alexander: and Messrs. Walker-Arnott, Falconer, Maughan, Stewart, Brand, Forbes, Munby, W. M'Nab, J. M'Nab, G. M. M'Nab, Tyacke, Wallich, Charlton, and Campbell.

Dr. Wallich was born at Calcutta in November 1815. His father, Dr. Nathaniel Wallich, was one of the greatest of the early Indian botanists—a worthy successor of Carey and Roxburgh. He will always be remembered as having given his name to an important genus of dwarf palms, which was named after him, *Wallichia*. The son, Dr. George Charles Wallich, was sent to Beverley, in Yorkshire, to school, and afterwards to the Reading Grammar School. He attended the Arts Classes in King's College, Aberdeen, and studied Medicine in Edinburgh, passing as a doctor there in 1836, and leaving immediately afterwards for Calcutta, where his father was superintendent of the Botanical Gardens.

At the meeting of the 17th March 1836, he was present as Mr. Wallich. In the first published list of members, dated 9th March 1837, his name appears as Dr. Wallich, Calcutta, non-resident. In the same list his father, Dr. Nathaniel Wallich, Calcutta, is entered as an honorary member.

In India, Dr. G. C. Wallich devoted himself to medicine, not science. He served in the Sutlej campaign in 1842 and the Punjab campaign in 1847, and received medals for each. In the Santal rebellion (1855–56) he held the important position of field-surgeon. I heard him described by an Indian contemporary as a first-rate medical officer, but without any of his father's taste for botany. The only paper published by him during this part of his career was "Some experiments tending to prove that the venous circulation is dependent on a vital act."

In 1858 he retired on account of bad health, having served twenty-two years in India. He resided two years in Guernsey, recovered his health, settled in London, and turned his attention to science, with such promise of success that, in 1860, he was recommended by Huxley and Sir Roderick Murchison for the post of naturalist to H.M.S. "Bulldog," commanded by Sir Leopold M'Clintock. This vessel was going to survey the Atlantic Ocean as a preliminary to laying down the Atlantic cable. While on board, Dr. Wallich made the important discovery that abundant animal life exists below the depth of a thousand fathoms. This was contrary to the belief then entertained by almost all scientific men.

Soon after his return to London, Dr. Wallich published "Notes on the presence of Animal Life at vast depths in the Ocean"; and in 1862 he published the first part of his great work, "The Atlantic Sea-bed." He afterwards published in "The Magazine of Natural History," "The Quarterly Journal of Microscopic Science," and other scientific periodicals, many papers on the distribution and life history of numerous forms of animal and vegetable pelagic organisms.

He took a prominent part in the Bathybius controversy. Huxley and Hæckel believed that *Bathybius Hœckelii,* a mixture of slime and lime brought up from the depths of the sea during the cable-laying experiments, was the lowest of known organisms. It was so described by Huxley in 1868, and by Hæckel in 1870.

On the other hand, Sir John Murray contended that it was only a gelatinous precipitate of sulphate of lime, precipitated from sea water mixed with alcohol.

At present the majority of scientific men believe that Murray and Wallich were right, Huxley and Hæckel wrong.

In 1898, Dr. Wallich was awarded the gold medal of the Linnean Society, in recognition of his researches into the problems connected with bathybial and pelagic life.

He died in London, on the 31st March 1899, in his eighty-fourth year, after a very exceptional career, having distinguished himself in youth as an operative surgeon,—in old age, as a man of science.

Obituary Notice of the late James Edward Tierney Aitchison, M.D., C.I.E., F.R.S., Surgeon-Major Bengal Army. By J. Rutherford Hill.

(Read 8th December 1898.)

James Edward Tierney Aitchison was the second son of Major James Aitchison, H.E.I.C.S., and was born at Nimach, Central India, on 28th October 1835. He accompanied his parents to Scotland in 1844, and attended the village school at Lasswade, Midlothian, where he had as a schoolmate the late Sir Charles Umpherston Aitchison. Afterwards he attended the Dalkeith High School and the Edinburgh Academy. From early childhood he had a desire to become a doctor, and from the Academy he passed to the University, where he studied Medicine and Surgery, and graduated M.D. and L.R.C.P. in 1856. He was of a very lively disposition, and fond of all sorts of games—quoits, cricket, tennis, etc. He was an abstainer and a non-smoker. He was very fond of reading history and travels. Both his parents are said to have had a great love of flowers; and his mother, Mary Turner, sister of John William Turner, Professor of Surgery in Edinburgh, had a knowledge of botany. It is interesting to note that in his student days he was an enthusiastic field botanist, and gained a first-class certificate in the botany class herbarium competition in 1854, for a collection of 530 plants, gathered, pressed, mounted, and arranged in the comparatively short period of four months. One of his fellow-students, Dr. Peter Hume M'Laren, informs me that he always showed a predilection for the pursuit of botany. Dr. M'Laren and he were colleagues

as dressers in Professor Syme's ward, and he knew him well. Dr. Aitchison's eldest sister was married to Rev. Dr. Gordon, of Newbattle, Dalkeith; and there young Aitchison spent his Saturday afternoons, and made the acquaintance of Miss Eleanor Carmichael Craig, the second daughter of Robert Craig, Esq., of Craigesk, whom he married in 1862. Mrs. Aitchison was a lady of charming manners, and entered sympathetically and enthusiastically into the special studies which engaged the attention of her husband. She was his constant companion in most of his travels, and it seems not improbable that her devotion may have injured her health.

In 1858, Dr. Aitchison entered the service of the Honourable East India Company, by competition, as assistant-surgeon, and he remained in the Indian Medical Service till 1888, when he retired with the rank of surgeon-major. Soon after his arrival in India, he began to take the same interest in Indian plants that he had already exhibited in the plants around Edinburgh. His great interest in tracing the origin of Indian drugs seems to have more and more led him to give his chief attention to botanical pursuits. Nevertheless he was frequently commended for unfailing diligence in medical and other official services. His duties took him into the districts of North-west India, Afghanistan, Beluchistan, Persia, and Turkestan; and the rich fields, and, to a large extent, virgin soil which these districts afforded for his favourite studies, begat in him a fascination which continued to the very last. As early as 1862, he sent a collection of between four and five hundred species to Kew, where there is a complete and extensive series of all the plants he collected.

His first paper, prepared while on sick-leave in England in 1862, was on "Flora of the Jhelum District of the Punjab" (Linn. Soc. Trans. Bot., vol. viii., 1863). This was followed by a paper "On the Vegetation of the Jhelum District of the Punjab" (Journ. of the Asiatic Society of Calcutta, vol. xxxiii., 1864); "Remarks on the Vegetation of the Islands of the Indus River" (Journ. of the Asiatic Society of Calcutta, vol. xxxiv., 1865); and "Lahul: its Flora and Vegetable Products, etc., from Com-

munications received from Rev. Heinrich Jaeschke of the Moravian Mission" (Linn. Soc. Journ. Bot., vol. x., 1868).

He was Civil Surgeon of Amritsur for two years, where he started a school for the education of native women as nurses, a service for which he was specially thanked by the Lieutenant-Governor of the Punjab. At Amritsur he was attacked with abscess of the liver, and left India in an apparently dying state. He was in England on sick-furlough for nearly three years, during which he devoted himself to botanical work, the result of which was the "Catalogue of the Plants of the Punjab and Sindh, etc.," published for the Author by Arthur G. Taylor & Francis, London, 1869. In 1872, he was appointed British Commissioner to Ladak, and the fruits of his work there are given in a "Handbook of the Products of Leh, with the Statistics of the Trade," published by Wyman & Co., Calcutta, in 1874. Of this handbook the Indian Foreign Secretary, Sir Charles Aitchison, said, "It is calculated to be of immense service to those interested in the trade with Thibet and Eastern Turkistan"; and Mr. Shaw, the Government Resident at Kashgar, said, "I doubt whether even here in Yarkand we shall be able to add much to your work. You seem to have left nothing unrecorded." His greatest work as an explorer and collector of botanical materials and local information was, however, done in Afghanistan and the surrounding countries.

During the winter of 1878, he served with the 29th Punjab Regiment, under Lord Roberts, in the advance up the Kuram Valley, at the taking of Peiwar Kotal, and in the advance to near the Shutar Gardan Pass; and he held the medal and clasp for the Kuram Valley campaign. In the following year, he was attached as botanist to the expedition, and made a very thorough exploration of the country between Thal and Shutar Gardan, collecting plants at all levels from 2000 to 13,000 feet. In this expedition he collected no less than 10,000 specimens, representing 950 species, and that under circumstances frequently of the greatest difficulty and danger. The results were embodied in a paper on "The Flora of the Kuram Valley, etc., of Afghanistan" (Linn. Soc. Journ. Bot., vol. xix. part ii., 1882). In 1884–85, he acted as naturalist on the

Afghan Delimitation Commission; and this expedition proved the most fruitful of all, the specimens amounting to about 10,000 specimens, representing 800 species, and 75 of them new to science, and of considerable economic and scientific importance. The results are given in the "Transactions of the Linnæan Society," and in a paper, "Some Plants of Afghanistan, and their Medicinal Products" (Pharm. Journ., 11th Dec. 1886). He again visited North-west India in 1894. He had hoped to go across into Persia to collect the plants yielding *Asafœtida*, *Opoponax*, *Sagapenum*, and *Galbanum*, as to which there is still some dubiety, but he was prevented by circumstances from doing so.

He sent to the Pharmaceutical Society specimens of the *Ammoniacum* plant, and of a plant he supposed to be *Galbanum*, though it was not, notwithstanding the very close resemblance of the leaves to the *Ferula galbaniflua*. He also sent home excellent herbarium specimens of *Ferula narthex*, from the original locality where Dr. Falconer found it in 1838. This is the same plant that flowered in the Edinburgh Botanic Garden. His enormous collections of material were sent to Kew, and have been largely worked up there. In 1863, he was elected a Fellow of the Linnæan Society. In 1881, he was elected a Fellow of the Royal Society of Edinburgh. In 1883, he was elected a Fellow of the Royal Society, and was created a C.I.E. In 1888, he became a Fellow of the Botanical Society of Edinburgh, and in the same year his Alma Mater conferred on him the honorary degree of LL.D. In 1891, he was elected an Honorary Member of the Pharmaceutical Society of Great Britain.

The papers contributed by him to our "Transactions" are:—"The Source of Badshaw or Royal Salep" (read December 1888). Dr. Lindley had previously declared the source to be a tulip, but Dr. Aitchison proved it to be the dried bulb of *Allium Macleanii*.—"A Summary of the Botanical Features of the County traversed by the Afghan Delimitation Committee during 1884–85" (read 11th April 1889). A good example of the interesting introductions to all his published papers on the Indian Flora, which give descriptions of the vegetation and local conditions of the

districts traversed.—"Notes to assist in a further knowledge of the Products of Western Afghanistan and of North-eastern Persia" (read 13th March 1890). A most elaborate and useful reference catalogue for all interested in the medicinal or economic products of these districts (Transactions, vol. xviii. part i.).—"Some Practical Hints relative to the Material required for a Botanical Expedition" (read 8th May 1890).

I had the privilege of considerable intercourse with Dr. Aitchison in the later years of his life. He was a man of fine presence, and most genial and kindly disposition. He seemed to preserve all the buoyancy and enthusiasm of youth, and was ever eager to encourage younger men who were inclined to follow him in his favourite pursuits. His tact and medical skill gained for him the confidence and goodwill of native tribes, and this greatly facilitated his labours in gathering information and material. He was not, and never claimed to be, a great scientific botanist. Indeed, he himself described only one of all the plants he ever collected. But by his enthusiasm and patience, and energy and powers of observation, he rendered immense service, especially in the department of economic botany, and he provided material, which he submitted to the skilled judgment of specialists. His extensive collections in North-west India, amounting to upwards of 20,000 specimens, embracing 1000 species, of which 75 were new to science, and one new genus, were made in a country almost at war with us, and where every man of the country valued the taking the life of a European and infidel as one of the means for securing his eternal welfare. The collecting was done under a continued state of suspense as to the safety of Dr. Aitchison's whole party, who daily, and frequently all night, were miles from any British guards, being protected by a few soldiers, or depending on the trustworthiness of the natives. This state of things made the collecting and storing of specimens a most arduous and laborious proceeding, great distances having often to be travelled with little result. Colonel Colquhoun in his book, "With the Kuram Field Force," says: "Dr. Aitchison's fame and skill as a medical man enabled him to visit all the outlying parts of the Kuram and Harriab

Valleys, attended only by a slight escort for the protection of his tents and stores; often alone, and always away from the neighbourhood of troops." These collections were made up into sets at Kew, and distributed to the following National and Public Museums in the following order:—1, Seharunpore; 2, Calcutta; 3, St. Petersburg; 4, Harvard University; 5, Boissin; 6, British Museum; 7, Florence; 8, Paris; 9, Berlin; 10, Copenhagen; 11, Lisbon; 12, Stockholm; 13, Mrs. Corson; 14, Edinburgh; 15, Zurich; 16, Mrs. Crepin (roses only). The first seven sets were complete, and the others less so, in the order given.

The last few years of his life were spent at Kew in preparing a "Flora Indiæ Desertæ," to include the plants of North-west India, Beluchistan, and Afghanistan. But he suffered much from a weak heart, and his ailments prevented the accomplishment of the task. The last year of his life was saddened by the loss of his wife, who died in July 1897. His name has been commemorated in botanical nomenclature by the Rubiaceous genus, *Aitchisonia*, by his friend and collaborateur, Mr. Hemsley. He died at Priory Terrace, Kew Green, on 30th September 1898, at the age of sixty-three, and was interred at Newbattle, Dalkeith. His death removes from our Roll the name of one of our most distinguished Fellows, who had endeared himself to us by many lovable qualities; and he leaves a vacancy which there is no living botanist at present to fill.

I am indebted to many friends for valuable aid in compiling this notice, especially to Professor and Mrs. Balfour, and Mr. E. M. Holmes, and to Miss Robina Orrock, who kindly obtained for me some important particulars of Dr. Aitchison's work in India, which were found among his papers by his surviving sister, Miss Aitchison.

TRANSACTIONS AND PROCEEDINGS

OF THE

BOTANICAL SOCIETY OF EDINBURGH.

SESSION LXIV.

Presidential Address. By Wm. Watson, M.D.

(Delivered 9th November 1899.)

As many of you are aware, the microbe which is the cause of Bombay and Hong-Kong plague was discovered in 1893 by a Japanese, named Kitasato, and it has been proved beyond dispute that this microbe is really the cause of plague, as a fluid prepared from the matter of the buboes, which occur in the course of the disease, has been successfully employed by Dr. Haffkine to inoculate human beings. The persons so inoculated suffer from a febrile attack, and undoubtedly acquire protection against attacks of plague.

The analogy to smallpox is perfect. Before vaccination was invented, this is exactly how people were inoculated to protect them against smallpox.

Of course, it is liable to the disadvantage that it may spread the disease. If plague matter is carried in tubes to a place where there is no plague, and people are inoculated, the disease is almost certain to spring up in an epidemic form, just as smallpox was spread in an epidemic form if people were inoculated in a locality where there was no smallpox.

This objection is, of course, obviated if only those are inoculated who live in an affected locality, but who have not themselves been attacked.

There are, however, still some questions in dispute regarding this microbe. Is it a flagellate bacillus, as Migula calls it, or is it a non-flagellate bacterium, as most authors think, or is it only one stage in the history of an organism which passes through a complex life-history?

Professor Koch tells us that outside the human body the plague microbe has a very brief vitality, at most eight or ten days, and that it is impossible to keep it alive longer than that. I believe all authorities are agreed on the truth of this statement.

We are therefore bound to inquire what becomes of the plague microbe during the long intervals that occur between two epidemics. It must be living somewhere or somehow, for the epidemics reappear at long intervals. In history, plague was first described as an Egyptian disease by Rufus, 100 A.D. It appeared in Europe in the time of Justinian, 567 A.D.; again as the Black Death, in 1347 A.D.; and lastly in 1655 A.D., in the time of Charles II. Since 1722 it has been confined to Asia and Africa.

In some parts of the Himalayas it reappears almost every autumn, and disappears at the beginning of next summer; but even this seasonal prevalence has to be accounted for.

We use the word microbe vaguely, but before we call an organism a bacterium, it must correspond to the botanical definition of the family of *Bacteriaceæ.* It must be a small single-celled plant, without chlorophyll, reproducing by cross division, or by the formation of spores, and almost always associated with decomposing albuminous substances. Now the plague microbe, outside the body of an animal, does not reproduce itself, either by division or by spore production, but sends off long threads, which drop off and fall down like stalactites, and then the organism perishes. As Dr. Patrick Manson said at the opening of the London School of Tropical Medicine—"Except in a very limited class, bacterial disease can be acquired anywhere and everywhere; the only exception to this generalisation is in the case of those bacterial diseases whose germ is a bacterium, which, though usually existing as a saprophyte, may, under certain circumstances, become parasitic."

By this, Dr. Manson means a plant having a complex

life-history, but which, in one stage of its history, looks like a bacterium.

There is, as Dr. Manson goes on to say, one well authenticated instance of such a bacterium, the *Micrococcus Melitensis*, the cause of Mediterranean fever. There are, however, other diseases, sometimes classed as bacterial, which are caused not by Schizomycetes, such as bacteria and bacilli are, but by plants like the Streptothrix of Actinomycosis, a disease common among cattle, and occasionally found among human beings, and the Streptothrix of Madura foot disease, an exceedingly common disease among human beings in Southern India, and in various other parts of the tropics.

These plants are not unicellular masses of protoplasm, but are composed of branched filaments, enclosed in a sheath, and reproducing by Conidia, like some of the higher fungi, not by simple division, or by solitary resting spores.

They have a complex life-history, having an independent existence outside the body of the man or animal which they attack.

In the case of Actinomycosis, there can be little doubt that, outside the bodies of cattle, the microbe exists as a parasite on various species of grain, generally barley, and that the animal is infected by eating this barley.

It is very important to keep clearly before our minds the distinction between a protophyte and a metaphyte, for the following reason:—

Protophytes multiply by simple division, so that it is easy to understand why, in their case, acquired characters are transmitted. Each of the new plants is simply one-half of the old one, neither more nor less.

In metaphytes, special cells are set apart early in the life-history of the plant for reproduction, and experience shows that characters acquired by the somatic cells do not pass to the reproductive cells, and are therefore not transmitted to the progeny. Why this should be so nobody knows. But the business of science is to ask the "*how*" of everything, the "*why*" of nothing.

Science has nothing to do with the word "*why*." It is probable, though not proved, that acquired characters

which have been acquired very early in the life-history of a metaphyte, before the differentiation of the reproductive cells, and at a time when the future metaphyte is still analogous to a protophyte, may be transmitted.

If this is the case, it would account for the occasional transmission of an acquired character.

From a medical point of view, the importance of the distinction between protophytes and metaphytes is very great, and lies in this: If the disease-carrying microbe be a protophyte, a slight change of environment will probably alter its properties more or less, and may make it more or less virulent. In the case of the anthrax bacillus, this was done by Pasteur, and in a different way by Professor Greenfield, of Edinburgh. On the other hand, if the disease-carrying microbe be a metaphyte, or one stage in the life-history of a metaphyte, such a change of properties is exceedingly improbable.

I wish now to read extracts from a paper on "Plague," which I wrote in 1876, when I was sanitary officer in the Himalayas.

It has value, for this reason, that as the people of the Upper Himalayas live in isolated villages, generally many miles apart, it is far easier to trace the history of an epidemic there, than it is when the epidemic occurs in crowded cities like Bombay, Poona, and Hong-Kong.

1. The Egyptian plague, the *Pestis Septica*, the *gola rog* (bubo disease) of Garhwál, is also known by the name of Máhámari (the great plague), under which name it was admirably described by Mr. Batten, of the Civil Service, in his letter to Government, North-Western Provinces, dated 1st January 1850. It is known from all other febrile diseases by the appearance (if the patient lives long enough) of buboes in the groin, in the armpit, or below the ear. It does not in any way resemble typhoid fever. There is no pain or tenderness in the right iliac region; no rose-coloured spots on the abdomen, or behind the shoulders; no diarrhœa, no well-marked morning remission; and lastly, death generally occurs about the third day, not about the twenty-first.

2. Of all known infectious diseases, with the possible exceptions of cholera and yellow fever, plague (*gola rog*) is

the most rapidly fatal. Death generally occurs within three or four days of the first symptom, often much earlier. If the patient can survive the eighth day, the buboes in the groin and elsewhere either subside of themselves or suppurate, and he often recovers. A patient I saw at Darmyari on the 9th May was believed by his friends to have recovered, and to be out of danger. Although it was only eight or nine days since he was first attacked, he was able to walk about, and had a fair appetite.

3. Of all known diseases, without any exception, plague (*gola rog*) has the shortest period of incubation.

The period of incubation of cholera is about forty-eight hours; the period of incubation of yellow fever, about the same; the period of incubation of smallpox, about twelve days; whereas the period of incubation of plague is certainly less than twenty-four hours,—consequently any person who has no symptom whatever for twenty-four hours after visiting an infected place may consider himself safe. This well-known law of Egyptian plague was well illustrated in the case of a woman who lived in the healthy village of Kheti, in Sili Chandpur. She slept one night in the infected village of Khirsál, in Sili Chandpur, and was attacked with plague next morning while walking home. She managed to reach her home, and the next day, a child living in her house was attacked. No other case occurred in any other house in Kheti village.

4. In Garhwál, as is well known, and as is mentioned by Dr. Renny, Dr. Pearson, Dr. Francis, and all other observers, the disease is remarkable from the fact that rats and mice often die in the houses in great numbers, some time before any human being is attacked. In some cases serpents are also found dead, and, though very rarely, jackals. Now rats and mice feed upon stored-up grain, like human beings. Serpents feed upon dead or dying rats. Jackals occasionally feed on dead bodies of persons who have died of the plague. The relations of the diseased often flee to the jungles, leaving the dead bodies lying in the village.

5. As far as is known, plague never occurs in cattle, sheep, or goats which feed on grass, shrubs, or rarely on growing corn.

6. As a rule, plague disappears in the hot weather. For this there are two reasons:—

First. Any temperature above 75° Fahr. destroys the infection of the Egyptian plague (Copland's "Dictionary of Medicine" p. 215, part ii.).

Second. The new corn is cut in the hot weather, so that the villagers are no longer obliged to eat their old grain, even when it happens to be thoroughly decayed, as it now and then is. Of course, the old grain is not decayed every year in every village, but it is occasionally, and then (I believe) it causes, if eaten, an outbreak of plague.

7. The disease always originates in out-of-the-way villages on high mountains, and spreads by infection to villages in the southern parganas; the reason being that the southern villages have a greater demand for their grain, and do not keep it in store for many years, as out-of-the-way villages occasionally do.

8. The disease is much less prevalent in Garhwál than it formerly was. This is owing to the villagers having a much better market for their grain than they formerly had, owing to the great increase of the number of pilgrims who annually visit the temples of Kedarnath and Badrinath.

9. The outbreaks of plague which occur in villages in Garhwál are of two kinds:—

First. Spontaneous outbreaks caused by eating damp grain.

Second. Outbreaks caused by infection brought from previously infected villages.

First.—When a spontaneous outbreak occurs, it will, I believe, be invariably found to have been preceded (or, more rarely, accompanied or followed) by a great mortality of the rats and mice in the village, showing that the grain has become poisonous. In these spontaneous outbreaks the mortality is very great, and the people do not escape the disease even though they flee to the jungle, unless, indeed, they also leave their grain behind, and get grain from some other village. A good example of this form I saw in the village of Kharki, near Pokri, where all the fourteen inhabitants of two houses died, most of them in the jungle.

Second.—In outbreaks caused by infection from a

previously infected village, it will generally be found that the person who brings the infection has slept a night in an infected house, or has eaten food in one. As an example of the former class of cases, there is the case of the woman of Kheti mentioned above, who slept a night in Khirsál. As an example of the latter class, there is the case of a barber of Pokri, who, leaving his village, then perfectly healthy, went and spent some hours in and got food from the spontaneously infected village of Kharki, where the fourteen persons died. In the case of imported plague, it is generally confined to the house of the person who brings the infection. Villagers who do not live in his house always escape if they flee, and even the people of his house often escape if they flee early. Nothing therefore can be more distinct than the respective histories of a spontaneous and of an imported outbreak of plague. In the former, the thing to be done is to burn the poisonous grain, and, perhaps, also the poisoned houses. In the latter, to burn the one infected house and to send its inhabitants away from the rest of the village, and away from everybody else. In Garhwál, spontaneous plague generally occurs in Rajput villages; imported plague, both in Dom and Rajput villages, but more frequently in the former.

10. There is every probability that the disease originates owing to some fungus unaffected by cooking being generated in decaying grain. It is evident therefore that it would be most important to ascertain what kind of fungus it is, and on what kind of grain it first forms. I have examined a good many species of grain, but hitherto without any satisfactory result. With regard to the kind of grain on which the fungus first forms, I am inclined to believe that it is probably mandua (*Eleusine coracana*). Several things lead me to suppose this, the most conclusive being that I have heard that at Balt, in Kumaun, a quantity of mandua was sent from the infected village of Balt to be ground at a water-mill. The rats of the water-mill, who had previously been healthy, all died after the mandua came to the water-mill.

11. There is one remarkable fact connected with the Garhwál plague which is difficult to explain. It is that

thousands of pilgrims from the plains pass every year through the infected country, and often buy grain from infected villages, and yet very few of them ever take plague. I have only heard of two cases of pilgrims dying of this disease. They were men who came last year from Trijogi Narayan, and died near the village of Unsari, not far from Okhimath, where the plague last year caused a very great mortality. This happened in November, and at that season Okhimath is a cold place. I have asked a number of patwáris, a number of native doctors attached to the pilgrim dispensaries, and many other people, and they all agree in saying that pilgrims from the plains are rarely affected. Three explanations of this may be given—

First. That the pilgrims generally wear cotton clothing, not woollen or hemp, like the hill men.

Second. The pilgrims rarely eat any of the kinds of grain which are peculiar to the hills, such as mandua (*Eleusine*), chúá (*Amaranth*), koni, jhingora, or china (three kinds of Panicum). They live almost entirely on wheat, barley, rice, and dal, which we must therefore suppose are substances which are not poisonous, even when brought from a village where the inhabitants are dying of plague. Consequently the pilgrims escape spontaneous outbreaks.

Third. They are not very likely to suffer from infection, because they only enter the hills in April, and follow a route which keeps pretty close to the valley of the Ganges, where, from April till October, the temperature even at night rarely falls below 75° Fahr. They are certainly in danger above Okhimath on the Kedarnáth road, and above Joshimath on the Badrinath road, but the pilgrims remain up in these cold regions as short a time as they possibly can. Besides, the air up there is very dry. And Copland (page 219) says that the infectious power of Egyptian plague is greatest in cold damp air; that it exists, but is not very powerful, in cold dry air; and that it does not exist at all in hot air, that is, any air whose temperature is above 75° Fahr.

12. Mr. Batten, in his letter of 1st January 1850, mentions the fact that European travellers and their

servants escape unscathed, even when they pass through plague villages. Exactly the same explanations apply to this case as to the case of the pilgrims.

13. Northern Garhwál is divided into four parganas—Painkhanda, to the north-east; Nagpur, with its Sadabart pattis, to the north-west; Badhan, to the south; Dasoli, in the centre. The habits of the people are identical, and the climate is very much the same in all the four. There is, however, a very great difference in their comparative liability to plague. Dr. Renny, in his notes for a report on Máhámari, dated 19th August 1850, writes in paragraph 1: "This remarkable distemper first broke out in Garhwál in the year 1823. It began near Kedarnath, and for some years confined its ravages to parganas Nagpur and Badhan." Nearly twenty-seven years have elapsed since Dr. Renny wrote this, and during these twenty-seven years there have been repeated outbreaks of plague in these two parganas, while there has rarely been any plague in Painkhanda or Dasoli, and yet the whole of Dasoli and part of Painkhanda lie between Nagpur and Badhan, separating the one plague district from the other. This year, in accordance with the usual law, there have been a great many deaths from plague in Nagpur and Badhan. There has not been a single death from plague in Painkhanda or Dasoli. I do not think sufficient attention has been paid to this remarkable phenomenon, and no explanation, as far as I know, has ever been attempted. From the year 1823 to the year 1877, that is to say, for fifty-four years, two tracts of country have suffered in the most frightful way from a very peculiar disease, and two other tracts, which may be said to lie between them, have scarcely suffered at all. Temperature will not explain it. Of the two very cold parganas, Painkhanda and Nagpur, one is healthy and the other not. Of the two comparatively warm parganas, Dasoli and Badhan, one is healthy and the other not. The only possible explanation I can see is, that the main pilgrim road to Badrinath passes through the two healthy parganas, and that consequently the people have always had a good market for their grain.

In conclusion, I wish to say that botanical problems, such as those of the life history of a fungus, can only be worked out by botanical specialists. Physiologists are, as a rule, microscopists rather than naturalists, and medical men direct their attention mainly to the treatment of disease, not to the life histories of plants.

There is little left to do in systematic botany, but the botanical student has before him boundless fields in the study of the life histories of algæ and fungi, and for the good of humanity no problem is at present more pressing than an inquiry into the life history of the plague microbe.

We know that *Puccinia Graminis* of wheat corresponds to *Æcidium Berberidis* of the barberry, but we do not know what corresponds to the short-lived microbe which was discovered by Kitasato.

I do not think that the views I hold are disproved by the experiments of Professor Hankin at Bombay. That gentleman has proved, by repeated and careful experiments, that if the germs of plague are placed among grain, they disappear in a few days. The same thing occurs in many cases where there is undoubtedly a long life-history. Before affecting the grain, the germs may have to pass through one or more intermediate stages.

I would explain the history of the outbreak of plague at Bombay in the following way:—

Bombay had been free from plague for centuries, but when an abundant supply of pure water was brought into the town from a distance without any compensatory system of drainage being instituted, the soil of the town became water-logged. Drainage was naturally very difficult, as most of the town is at the sea-level. The soil being water-logged the cereal grains, especially the millets, stored in the granaries became damp, and the plague fungus attacked the stored grains.

I would account for the fact, that the natives suffered much and the Europeans suffered little, by connecting this with another fact, which is that of the cereals: Europeans eat only wheat, and natives eat chiefly millet, so that it is perfectly analogous to what I saw in the Himalayas,

where Hindoos, who eat wheat and rice, escaped plague, whilst those who ate the millets suffered from it. Of course Europeans were liable to the secondary or milder form of the disease—that is to say, they were liable to infection through the air from persons who had contracted the primary form of the disease by eating decayed millets.

I have often thought that epidemics of plague may have occurred in prehistoric times, and may have from time to time affected mankind ever since they began to make use of cereals. At all events, an early epidemic is recorded in the Bible—in the first Book of Samuel, chapters v. and vi. (revised version). We are told there that a great pestilence broke out among the Philistines, and that the men that died not were smitten with tumours. Their priests and diviners advised them to make golden images of tumours and of mice, for evidently in this epidemic, as in all later ones, mice suffered equally with men, since both feed on grain. The pestilence is said to have lasted seven months, and to have ended when the wheat harvest was being reaped in spring, and the people had fresh grain to eat (1 Sam. vi. 13).

In the plains of Sharon and in the plains of Philistia, millets were doubtless cultivated then as they are now, though the principal crops may have been wheat and barley. It is probable that the millets were more cultivated at that time in the country of the Philistines than they are now, for the introduction of the American plant—maize—(Zea mays) has caused the millets of the genera *Panicum*, *Paspalum*, and *Eleusine* to be less cultivated than they were.

More Notes on Tree Measurements. By C. E. Hall. Communicated by Dr. Christison. (With Diagrams.)

(Read 9th November 1899.)

In vol. xviii., 1890, of the "Transactions of the Botanical Society of Edinburgh" will be found "Notes of Tree Measurements at San Jorge, Uruguay," from 12th January 1885 to 12th January 1890.

Monthly measurements of most of these trees have been made continuously up to the present date. I am thus enabled to compare the growth of sixteen of those trees in these first five years, with their growth in the last nine years.

As stated in the "Notes" of 1890, the measuring day has always been as nearly as possible on the 12th day of each month. The trees are marked with a lightly painted line, three feet above the ground, which is the measuring-point. The measure used is a steel tape, marked to millimetres; and the measurements have always been taken with care, to secure as great accuracy as possible.

The sixteen trees whose measurements are continuous from 12th January 1885 to 12th January 1899, are as follows:—

EVERGREENS.—Two Eucalypti (common varieties, but not *Eucalyptus globulus*, or blue gum); now about 18 years old. Two Stone Pines (*Pinus pinea*); about 21 and 23 years old. Two Blackwoods (*Acacia melanoxylon*); now about 19 years old.

DECIDUOUS TREES.—Two Oaks, from English acorns, but I do not know if *Quercus robur* or not; about 21 years old. Two Paraisos (*Melia azedarach*); about 18 years old. Two Lombardy Poplars (*Populus fastigiata*); doubtful age, possibly about 22 years. One Robinia (*Robinia pseudo-Acacia*); now about 19 years old. I have multiplied the growth of this tree by two, for purposes of comparison.

OTHER DECIDUOUS TREES.—One Paraiso; possibly 42 years old. One Acer (*pseudo-platanus*); about 25 years old perhaps. One Cottonwood (*Populus angulata*); about 18 years old.

All these have been growing in enclosed ground, and in undisturbed grass, except the two oaks and the cotton-wood; and the ground round them has been undisturbed for the last five or six years.

A reference to the "Notes" of 1890 will show that of the twenty trees then measured, two *Acacias dealbata*, one young Robinia, and one old Robinia are not now among the trees measured. The two Dealbatas began to make much dead wood. Their growth during the two years 1890–91 amounted to 350 millimetres, and during the two years

1892–93 to only 167 millimetres. If to this total growth of 517 millimetres for four years be added one-fourth—129 millimetres—the growth for five years would be 646 millimetres, or 807 millimetres less than 1453 millimetres, the growth in the five years 1885–90. The two trees were felled in 1894.

The younger Robinia grew only 6 millimetres in the three years 1890–92; and showed a decrease of 4 millimetres in 1893, when it was felled. It was evidently unhealthy.

The older Robinia was felled with the rest of the avenue in which it stood.

I now present Table I., showing the average monthly growth in millimetres of six evergreens for the term of nine years, with the percentages of growth per month, as well as the percentages of monthly growth for the five-year term, and for the whole fourteen-year term, calculated independently.

TABLE I.—Monthly Increase of Evergreens for Nine Years; and Percentages of Monthly Increase for terms of Five, Nine, and Fourteen Years.

	Two Eucalypti.				Two Pines.				Two Blackwoods.			
	Millimetres.	Percentages.			Millimetres.	Percentages.			Millimetres.	Percentages.		
		5 Years.	9 Years.	14 Years.		5 Years.	9 Years.	14 Years.		5 Years.	9 Years.	14 Years.
January	140	9·2	8·0	8·5	56	6·7	6·2	6·5	102	14·5	15·1	14·7
February	169	9·0	9·7	9·4	44	6·0	4·9	5·4	83	7·9	12·3	9·8
March	186	11·5	10·7	11·0	136	6·7	15·0	10·7	89	9·4	13·2	11·0
April	196	10·9	11·3	11·1	82	9·4	9·0	9·2	52	10·7	7·7	9·4
May	151	9·5	8·7	9·0	25	7·1	2·8	5·0	30	9·4	4·4	7·2
June	85	8·0	4·9	6·1	28	2·9	3·1	3·0	9	3·9	1·3	2·8
July	154	4·8	8·9	7·3	50	1·5	5·5	3·5	37	2·0	5·5	3·5
August	153	5·7	8·9	7·6	132	6·7	14·6	10·5	16	3·1	2·3	2·8
September	167	9·5	9·6	9·6	137	16·3	15·1	15·7	72	5·7	10·7	7·9
October	91	8·6	5·2	6·6	94	15·1	10·4	12·9	87	13·5	12·9	13·2
November	127	6·8	7·3	7·1	90	12·0	10·0	11·0	57	11·8	8·4	10·4
December	119	6·5	6·8	6·7	31	9·6	3·4	6·6	42	8·1	6·2	7·8
	1738	100	100	100	905	100	100	100	676	100	100	100

This Table I. shows that for Gum trees and Blackwoods the month of least growth is June (= English December), and May for Pines. In the years 1885–90, July was the month of least growth for all three species. The Gums grow most in April. In 1885–90, March showed as much

growth as April; and the growth of the Gum trees is very fairly distributed over the whole year, rather more so than in 1885–90.

The Pines grow most in September, as they did in the five-year period. The fact that they have two periods of chief growth, March and September—and May and December as months of least growth—contrasts with the records of 1885–90, when 53 per cent. of the growth occurred in the four months September to December inclusive; and the next best growth was 9 per cent., in April.

The Blackwoods grow most in January, as in the five-year period. January and October are their months of best growth, as in the five-year period: and June and August their months of least growth. July and August being months of least growth in 1885–90.

Table II. gives the monthly increase for nine years, and percentages for the three periods, for six deciduous trees: and one Robinia multiplied by 2.

TABLE II.—Monthly Increase of Deciduous Trees for Nine Years; and Percentages of Increase for Five, Nine, and Fourteen Years.

	Two Paraisos.				Two Oaks.				Two Poplars.				One Robinia × 2.			
	Millimetres.	Percentages.			Millimetres.	Percentages.			Millimetres.	Percentages.			Millimetres.	Percentages.		
		5 Years.	9 Years.	14 Years.		5 Years.	9 Years.	14 Years.		5 Years.	9 Years.	14 Years.		5 Years.	9 Years.	14 Years.
January .	50	22·8	14·3	19·7	36	19·7	5·8	13·3	46	21·1	12·8	17·8	14	18·7	7·7	14·4
February .	16	21·6	4·6	15·3	29	13·9	4·7	9·6	18	13·2	5·0	10·0	14	21·8	7·7	16·3
March . .	6	11·4	**1·7**	7·8	6	5·8	1·0	3·6	**1**	2·8	**0·3**	1·6	1	3·2	**0·5**	1·7
April . .	15	3·6	4·3	3·8	11	1·6	1·7	1·7	3	3·9	0·8	2·7	15	4·2	8·2	5·8
May . . .	**4**	**1·5**	**1·1**	**1·4**	**2**	**0·4**	**0·3**	**0·4**	..	**2·8**	..	**1·7**	**3**	**3·2**	**1·6**	**2·6**
June . .	14	0·7	4·0	1·9	**6**	0·3	**1·0**	**0·3**	13	0·5	3·6	1·7	..	1·8	..	1·1
July . .	14	1·2	4·0	2·2	11	0·3	1·7	1·0	**20**	**0·3**	**5·5**	**2·4**	6	1·4	3·3	2·1
August .	13	0·8	3·7	1·9	21	0·3	3·4	1·7	10	0·5	2·8	1·4	11	1·1	6·0	3·0
September .	61	5·8	17·5	10·2	86	1·0	13·8	7·0	27	0·5	7·5	3·3	32	2·5	17·6	8·4
October .	50	6·1	14·3	9·2	178	9·4	28·6	18·3	79	5·5	21·9	11·9	34	9·5	18·7	13·1
November .	55	8·9	15·8	11·4	187	25·0	30·1	27·3	129	26·9	35·8	30·4	51	17·9	28·0	21·9
December .	59	18·6	16·9	18·0	65	23·1	10·5	17·2	56	28·2	15·6	23·3	9	21·1	4·9	14·8
	349	100	100	100	622	100	100	100	360	100	100	100	182	100	100	100

Decreases are printed in heavier type.

May shows a decrease in three species, and no growth in the Poplars. This differs from the period 1885–90, when all the four species showed decrease in May, and the Poplars as much as 3 per cent. These Poplars in the

earlier term showed also 0·3 per cent. decrease in July; and now, in the nine-year period, show 5·5 per cent. decrease in July, and 0·3 per cent. decrease in March.

The Robinia also decreases in March, and the other two species have a minimum of growth; all four species, notably Robinia, improving a little in April, before their May losses. The Poplars, also, recover something in June, before their chief loss in July.

The Oaks suffer a heavier loss in June than in May.

November is the month of chief growth for Oaks, Poplars, and Robinia; and December for Paraiso. In the five-year period, Oaks and Poplars grew most in November, Robinia in February, and Paraiso in January.

Perhaps the chief point of contrast between the first and second periods—1885–90, and 1890–99—is the decrease, or minimum growth, in all species in March in the second period, 1·9 per cent., against 23 per cent. in the first period; and the very small growth in the first period, during the months of June, July, and August, only 8·6 per cent., against 26 per cent. in these three months in the second period.

It may possibly be deduced from this that younger trees have a more pronounced sleeping season than older trees, and that older trees indulge in a brief preliminary siesta when, in March, summer is yielding to autumn.

If the year be divided into growing and sleeping halves—September to February inclusive, and March to August—we find the following percentages of growth:—

	Growing Season.		Sleeping Season.	
	1st Period.	2nd Period.	1st Period.	2nd Period.
Paraisos .	84	83·4	16	16·6
Oaks . .	92	93·5	8	6·5
Poplars .	$95\frac{1}{3}$	98·6	$4\frac{2}{3}$	1·4
Robinia .	$91\frac{1}{2}$	84·6	$8\frac{1}{2}$	15·4
	$326\frac{5}{6}$	360·1	$37\frac{1}{6}$	39·9

The very small growth in March—1·9 per cent. in the nine-year period, contrasted with the 23 per cent. in the first period—is the reason why this table does not show any very marked difference between the first and second sleeping seasons, except in the case of the Robinia.

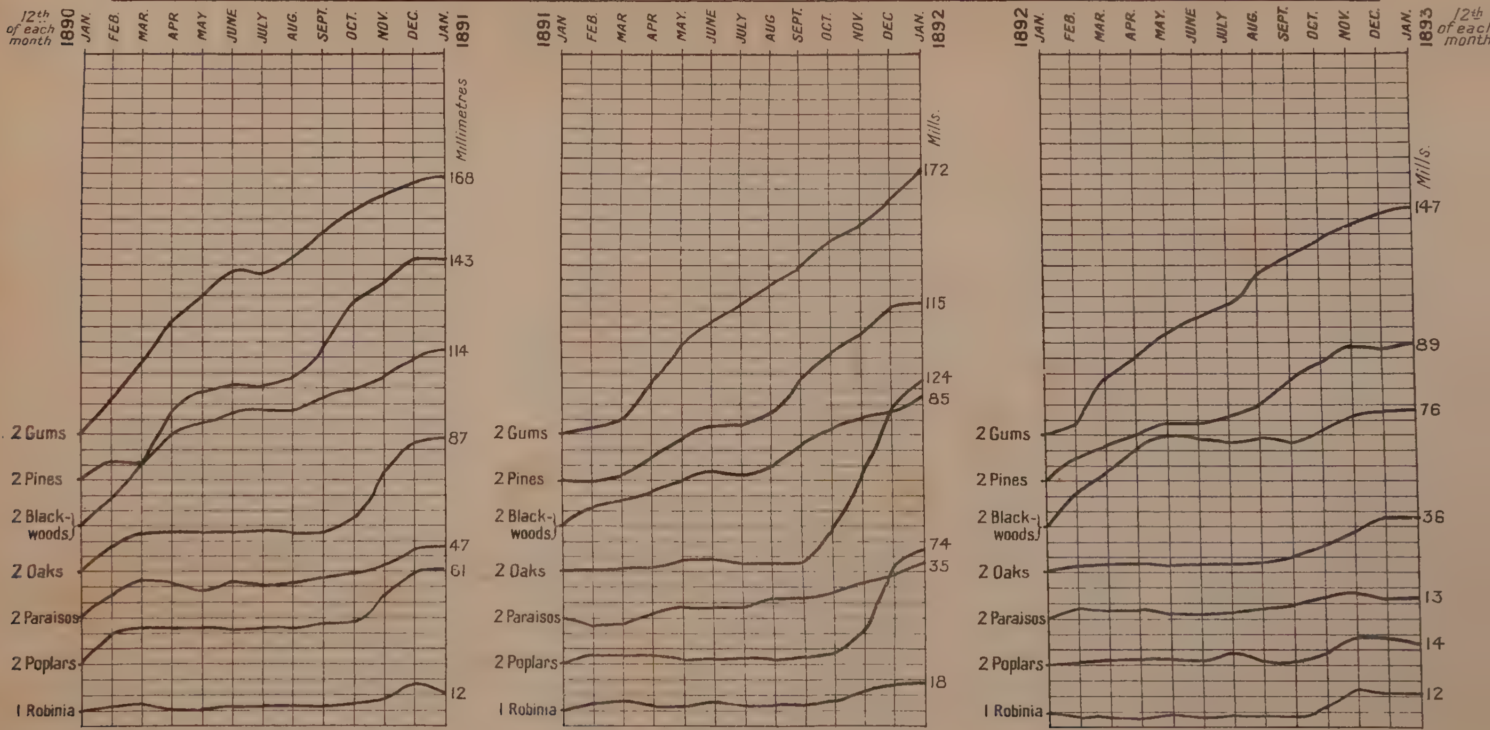
TABLE III.—Monthly Increase of Three Deciduous Trees for Nine Years; and Percentages of Increase for Five, Nine, and Fourteen Years.

	PARAISO.				ACER.				COTTONWOOD.			
	Millimetres.	Percentages.			Millimetres.	Percentages.			Millimetres.	Percentages.		
		5 Years.	9 Years.	14 Years.		5 Years.	9 Years.	14 Years.		5 Years.	9 Years.	14 Years.
January	37	17·3	19·9	18·6	31	22·2	8·2	15·2	85	22·8	13·7	18·0
February	29	22·5	15·6	19·1	40	12·9	10·4	11·6	53	16·3	8·6	12·2
March	3	1·0	1·6	0·3	14	8·3	3·6	6·0	27	9·7	4·4	6·8
April	13	4·7	7·0	1·1	4	5·7	1·0	3·4	13	4·7	2·1	3·3
May	3	4·7	1·6	3·2	3	1·5	0·8	1·2	11	0·7	1·8	1·3
June	1	5·8	0·5	2·7	5	1·5	1·3	1·4	4	0·3	0·6	0·5
July	26	4·7	14·0	4·5	2	0·3	0·5	0·1	3	0·2	0·5	0·2
August	1	3·7	0·5	1·6	1	0·5	0·3	0·1	10	1·1	1·6	1·4
September	32	10·5	17·2	13·8	25	0·5	6·5	3·5	28	0·3	4·5	2·6
October	32	11·5	17·2	14·3	99	3·4	25·7	14·5	116	5·4	18·7	12·5
November	26	14·1	14·0	14·1	116	23·3	30·1	26·7	169	18·7	27·3	23·3
December	25	18·3	13·3	15·9	51	24·5	13·2	18·9	129	21·2	20·8	20·9
	186	100	100	100	385	100	100	100	620	100	100	100

Table III. shows the growth of the Paraiso in nine years to have been 186 millimetres, whereas in the five-year period its growth was 191 millimetres; thus its rate-growth in the second period was little more than half its rate-growth in the first period. It is remarkable that in the first period this tree decreased 4·7 per cent. in July, and in the second period increased 14 per cent. in that month, actually followed by a slight decrease in August. No other deciduous tree behaves in this extraordinary manner. Its measurement record for nine Julys is—Naught; 5 millimetres; Naught; 2 millimetres; 5 millimetres; 5 millimetres; 4 millimetres; 1 millimetre; 6 millimetres,—equal to 28 millimetres.

The Acer in this second period distributes its chief growth over six months, whereas in the first period its chief growth was confined to, at most, five months; and it seems to begin its chief growth a month earlier (October) in the later than in the former period (November); as also does the Cottonwood, which, like the *Populus fastigiata*, has a decrease in July, but slight in comparison with its May loss. All three of these trees show a decrease in May.

MONTHLY AND YEARLY INCREMENTS IN TREE-GIRTHS; Average taken of two Trees in each class in Millimetres.

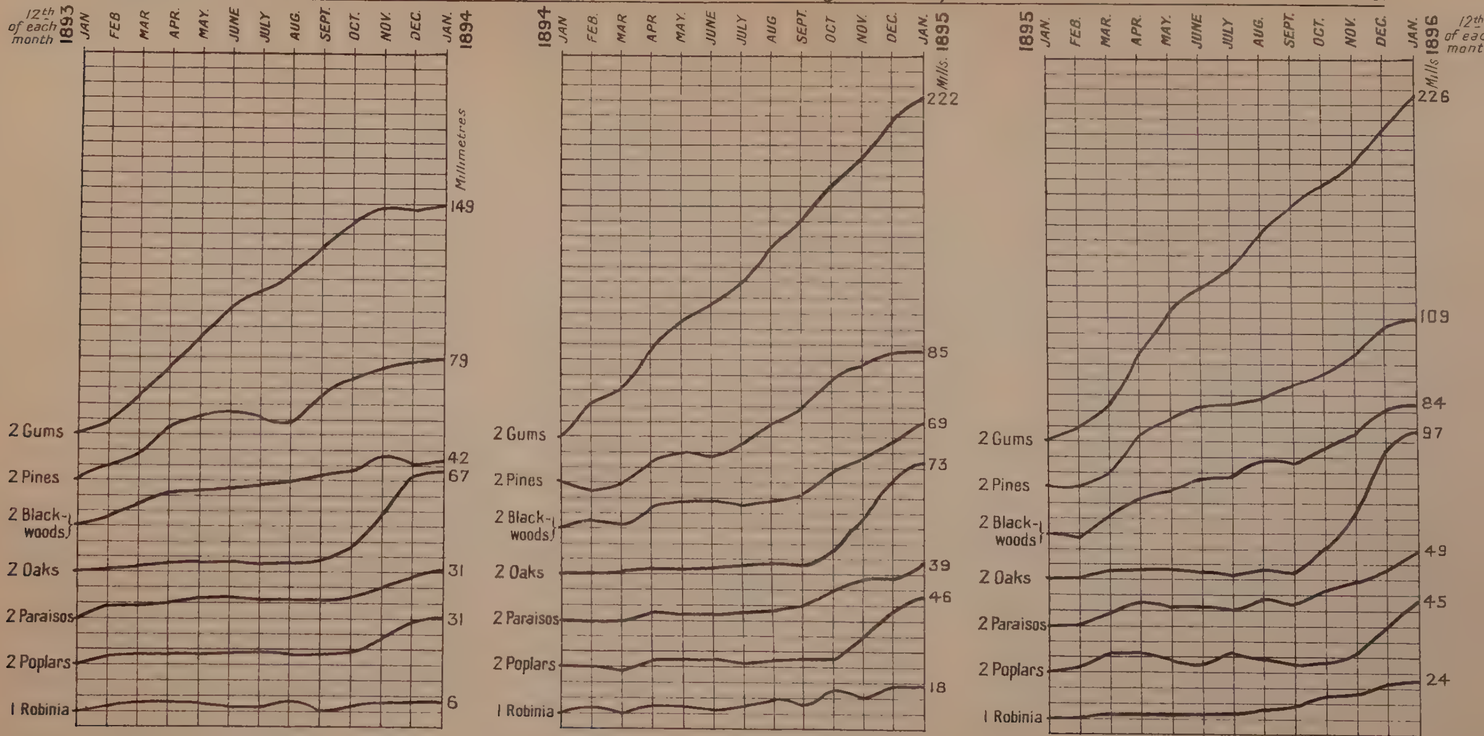


Average Annual Inches of Rain.... 36·14
" " Hours of Sunshine.. 3192
" " Mean Temperature.. 59°·4

Average Annual Inches of Rain.... 48·69
" " Hours of Sunshine.. 3065
" " Mean Temperature.. 61°·3

Average Annual Inches of Rain.... 23·41
" " Hours of Sunshine.. 3345
" " Mean Temperature.. 60°·8

MONTHLY AND YEARLY INCREMENTS IN TREE-GIRTHS; Average taken of two Trees in each class in Millimetres.

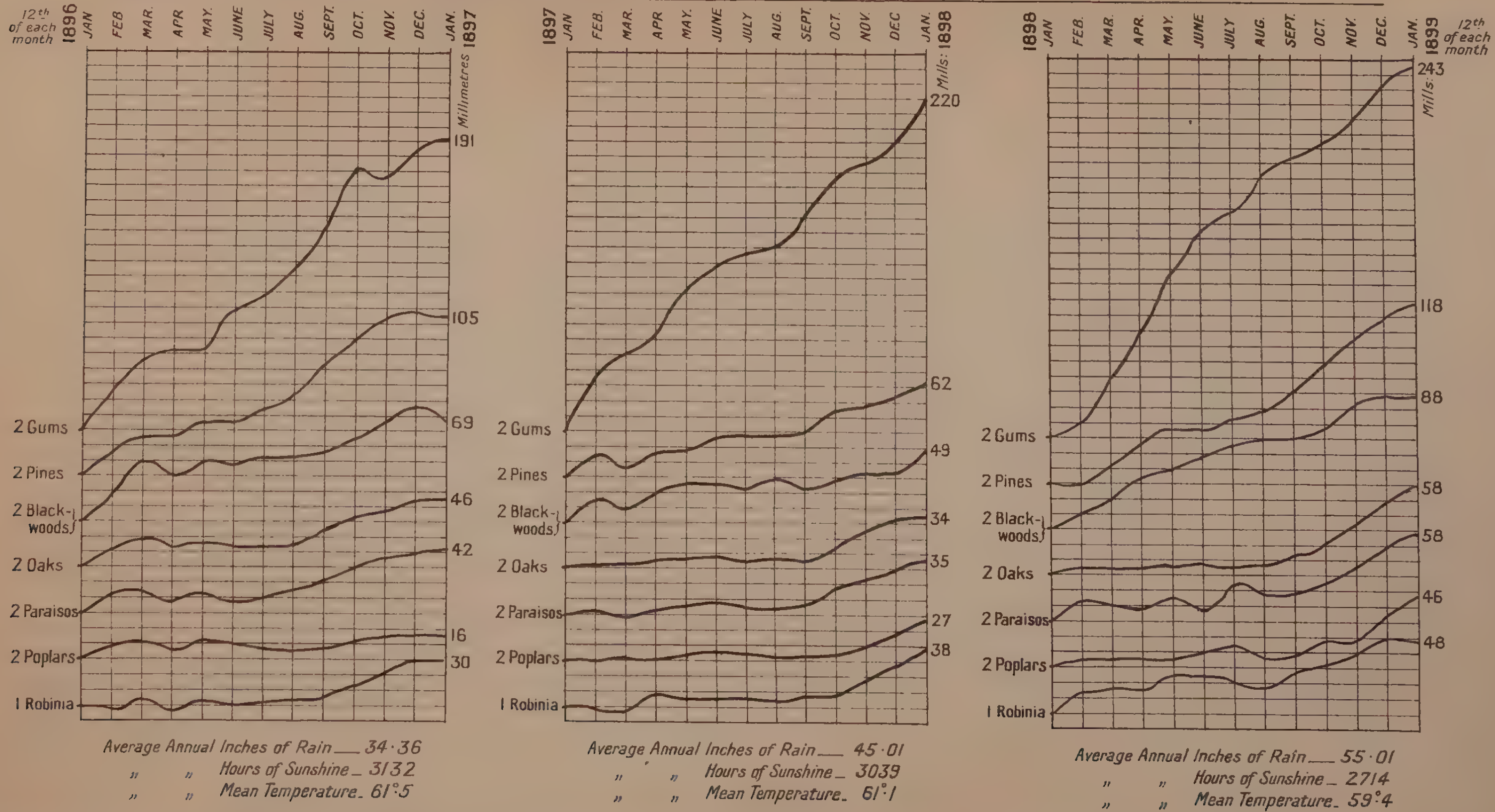


Average Annual Inches of Rain ___ 39·58
" " Hours of Sunshine _ 3132
" " Mean Temperature _ 59°·9

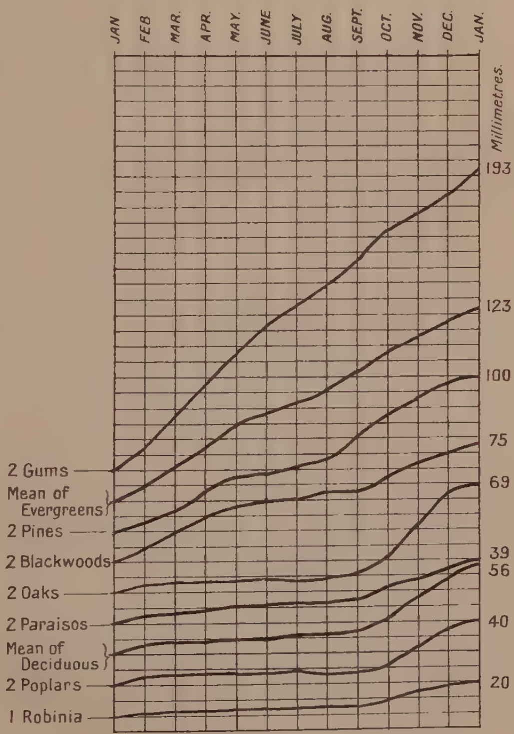
Average Annual Inches of Rain ___ 40·50
" " Hours of Sunshine _ 3141
" " Mean Temperature _ 60°·5

Average Annual Inches of Rain ___ 55·42
" " Hours of Sunshine _ 3009
" " Mean Temperature _ 61°·3

MONTHLY AND YEARLY INCREMENTS IN TREE-GIRTHS; Average taken of two Trees in each class in Millimetres.



AVERAGE MONTHLY INCREMENT IN TREE-GIRTHS FOR NINE YEARS 1890-98.



Average Annual Inches of Rain — 42·01
" " Hours of Sunshine — 3085
" " Mean Temperature — 60°6

Dividing the year into growing and sleeping halves, these trees show the following percentages of growth :—

	Growing Season.		Sleeping Season.	
	1st Period.	2nd Period.	1st Period.	2nd Period.
Paraiso . .	94½	97·2	5½	2·8
Acer . .	87	94·1	13	5·9
Cottonwood	84½	93·6	15½	6·4
	266	284·9	34	15·1

In these three trees, the second period shows a much more marked contrast between growing and sleeping seasons than in the other seven deciduous trees, notably so in the case of the old Paraiso—97·2 per cent. in six months, against 83·4 per cent. of the young Paraisos. Also, in this second period, the rate of growth of these three trees is less than half what it was in the first period during the sleeping season.

Table IV. collects the monthly averages of growth of the six evergreens in Table I., the seven deciduous in Table II., and the three deciduous in Table III., and gives their percentages of increase for five, nine, and fourteen years.

Table IV.—Totals of Monthly Growths of Trees in Tables I., II., and III. for Nine Years; and Percentages of Growth for Five, Nine, and Fourteen Years.

	I.—Six Evergreens.				II. Seven Deciduous.				III. Three Deciduous.			
	Millimetres.	Percentages.			Millimetres.	Percentages.			Millimetres.	Percentages.		
		5 Years.	9 Years.	14 Years.		5 Years.	9 Years.	14 Years.		5 Years.	9 Years.	14 Years.
January . .	298	9·9	9·0	9·4	146	20·8	9·6	16·2	153	21·7	12·9	17·1
February . .	296	7·7	9·0	8·4	77	17·0	5·1	12·0	122	16·0	10·2	13·1
March . .	411	9·3	12·4	10·9	10	6·0	0·7	3·9	38	7·7	3·2	5·4
April . . .	330	10·3	10·0	10·1	44	3·2	3·0	3·1	4	5·0	0·3	2·6
May . . .	206	8·7	6·2	7·4	**9**	**1·8**	**0·6**	**1·2**	**17**	**1·7**	**1·4**	**1·6**
June . . .	122	5·1	3·6	4·3	21	0·6	1·4	0·9	8	1·7	0·7	1·2
July . . .	241	2·9	7·2	5·2	11	0·6	0·7	0·6	25	**0·8**	2·1	0·7
August . .	301	5·3	9·1	7·3	55	0·6	3·6	1·8	10	1·0	0·9	0·9
September . .	376	10·6	11·3	11·0	206	2·4	13·6	7·0	85	2·2	7·1	4·7
October . .	272	12·2	8·2	10·1	341	7·4	22·5	13·7	247	5·8	20·7	13·5
November . .	274	10·0	8·2	9·1	422	20·3	27·9	23·4	311	19·5	26·1	22·9
December . .	192	8·0	5·8	6·8	189	22·9	12·5	18·6	205	21·9	17·2	19·5
	3319	100	100	100	1513	100	100	100	1191	100	100	100

This Table IV. shows that in the nine-year period the chief growth in the evergreen group is in March, September coming next; and their least growth in June, December

coming next. Whereas in the five-year period their chief growth was in October, September again ranking next; and their least growth in July, December being a month of good growth, and March just over an average month.

In the two groups of deciduous trees, November shows most growth in the nine-year period; while, in the five-year period, December shows most, January coming next. In both periods, May shows a decrease of girth in all deciduous trees measured.

Dividing the year into growing and sleeping halves, we obtain the following comparisons of percentages of growth, the first and second periods agreeing fairly well:—

	Growing Season.		Sleeping Season.	
	1st Period.	2nd Period.	1st Period.	2nd Period.
6 Evergreens	61	51·5	39	48·5
7 Deciduous	91	91·2	9	8·8
3 Deciduous	88½	94·2	11½	5·8
	240½	236·9	59½	63·1

Table V. shows the girth of each individual tree on 12th January 1890 and 12th January 1899, the increase of each tree, the average annual increase for nine years and also for five years, all in millimetres.

TABLE V.—Girth of Trees, and Increase in Nine Years.

	Group of Table I.						
	Gum Trees.		Pines.		Blackwoods.		Six Evergreens.
Girths, January 1899	1746	1491	1559	1467	932	1460	8655
Girths, January 1890	774	725	1141	980	727	989	5336
Increase in Nine Years	972	766	418	487	205	471	3319
Average Annual Increase	108	85	46	54	23	52	61
Do. do. Five Years	112	108	87	107	66	108	110

	Group of Table II.							
	Paraisos.		Oaks.		Poplars.		Robinia.	Seven Deciduous.
Girths, January 1899	792	768	872	814	1008	865	536	5655
Girths, January 1890	609	602	492	572	809	704	433	4221
Increase in Nine Years	183	166	380	242	199	161	103	1434
Average Annual Increase	20	18	44	27	22	18	11	23
Do. do. Five Years	61	56	66	79	50	62	{ 32 25 }	54

TABLE V.—*continued.*

	Group of Table III.			
	Paraiso.	Acer.	Cottonwood	Three Deciduous.
Girths, January 1899	1632	1055	1375	4062
Girths, January 1890	1446	670	755	2871
Increase in Nine Years	186	385	620	1191
Average Annual Increase	21	43	67	44
Do. do. Five Years	38	103	77	73

The Gum trees maintain nearly the same rate of growth in the second period as in the first, and the Cottonwood likewise; but all other trees show a very considerably diminished rate, varying, roughly, from a half to a third part of the five-year rate. It seems strange that the older Paraiso, a tree of at least twenty-eight years in 1885, should show such a diminished rate of growth. Its annual rate for the last nine years has been 17, 16, 9, 20, 21, 25, 30, 42, and 6—in all 186—millimetres; and this does not look as if the tree were unhealthy. And why one Oak should grow so much better than the other is also strange; they are on just the same ground, and within fifteen yards of each other.

Thus far, only the monthly growths and percentages of growth have been commented on, and the inequalities of annual growth, due partly to the varying weather of different years, partly to the advancing ages of the trees, may present points of interest; and I, therefore, tabulate (No. VI.) the annual growth of these sixteen trees for fourteen years, giving for each growing and sleeping season the plus or minus average of inches of rainfall, of estimated hours of sunshine, and of means of maxima and minima thermometer readings, taking the first and last three months of each year as growing season, and the middle six months as sleeping season.

In the first four years, the growth of evergreens is fairly equal: in 1889, they show a considerable increase of growth, and in that year, both in growing and sleeping seasons, the rainfall was greatly in excess; there was a great deficiency of sunshine; and temperature, generally, was below normal. Then come three years of gradually

TABLE VI.—Showing the Annual Growth in Millimetres of Sixteen Trees for Fourteen Years; with some Weather Notes for the same Years.

	Gum Trees.		Pines.		Blackwoods.		Totals of Evergreens.	Paraisos.		Oaks.		Poplars.		Robinias.		Paraiso.	Acer.	Cottonwood.	Totals of Deciduous.	Years.	Growing Season. Plus or Minus of—				Sleeping Season. Plus or Minus of—			
																					Rain.	Sun.	Means of— Max.	Means of— Min.	Rain.	Sun.	Means of— Max.	Means of— Min.
1885 . .	100	100	92	119	68	99	578	88	64	78	71	59	70	51	50	57	74	103	765	1885	7·66	**161**	1·2	0·7	**0·84**	**131**	**2·1**	**0·6**
1886 . .	97	133	83	104	56	93	566	69	60	57	71	50	92	36	20	20	57	87	610	1886	**8·80**	**24**	**0·2**	**0·6**	1·99	**19**	**0·6**	**0·9**
1887 . .	59	65	92	108	82	117	523	59	56	69	91	36	44	39	22	41	61	96	605	1887	**3·22**	**57**	**0·4**	**0·1**	**6·10**	23	1·4	0·7
1888 . .	113	121	80	93	47	95	549	43	45	62	85	51	47	25	21	42	69	96	586	1888	**4·01**	**147**	**0·6**	1·9	9·74	**151**	**0·5**	1·5
1889 . .	169	144	89	109	79	136	726	55	58	73	76	56	58	10	10	31	126	157	710	1889	14·19	**155**	**1·8**	0·9	11·18	**163**	**1·5**	**0·2**
1890 . .	87	81	66	77	38	76	425	21	26	40	47	30	31	2	6	17	54	118	392	1890	**3·50**	102	1·0	**2·6**	**4·81**	114	0·5	**2·5**
1891 . .	102	70	47	68	32	53	372	18	17	68	56	36	38	3	9	16	57	77	395	1891	**1·10**	59	0·4	0·6	5·34	30	0·1	2·1
1892 . .	89	58	39	50	22	54	312	7	6	16	20	9	5	1	6	9	37	52	168	1892	**5·60**	124	1·6	**0·3**	**15·44**	245	1·6	**2·2**
1893 . .	83	66	36	43	13	29	270	16	15	43	24	19	12	**4**	3	20	30	35	213	1893	**2·24**	163	0·7	..	**2·63**	**7**	**2·6**	**0·6**
1894 . .	142	80	44	41	22	47	376	21	18	46	27	28	18	..	9	21	33	55	276	1894	**1·52**	114	0·3	0·3	**2·43**	51	**0·4**	**0·2**
1895 . .	135	91	51	58	24	60	419	28	21	65	32	25	20	..	12	25	43	63	334	1895	7·15	**53**	**1·1**	0·6	3·82	86	0·9	2·9
1896 . .	111	80	52	53	16	53	365	22	20	29	17	6	10	..	15	30	36	72	257	1896	**6·18**	43	**0·8**	**1·0**	**3·91**	113	4·8	0·9
1897 . .	138	82	24	38	13	36	331	17	18	24	10	18	9	..	19	42	32	53	242	1897	2·46	79	1·8	0·9	**1·90**	**16**	**0·2**	**0·2**
1898 . .	134	109	59	59	25	63	449	33	25	49	9	28	18	..	24	6	63	95	350	1898	4·72	**94**	**1·6**	**1·3**	5·84	**168**	**1·2**	**0·4**
Totals .	1559	1280	854	1020	537	1011	6261	488	449	710	636	451	472	163	226	377	772	1159	5903									
Girths, 1885	187	211	705	447	395	449	2394	304	319	162	178	557	393	252	310	1255	283	216	4239									
Girths, 1899	1746	1491	1559	1467	932	1460	8655	792	768	872	814	1008	865	415	536	1632	1055	1375	10,132									

decreasing growth, culminating in 1893, the worst year for growth out of the fourteen. That year the rainfall was slightly deficient in both seasons, and there was a great excess of sunshine in the growing season; in the sleeping season, the temperature was below normal. In the previous year (1892) the growth was nearly as bad, and the deficiency of rain was more than four times as much as in the worst year of growth (1893). The temperature in both seasons was higher than in 1893, but had a low mean of minima in the sleeping season; and the sunshine, in excess in the growing season, was particularly abundant in the sleeping season.

The growths of 1891 and 1894 are nearly equal, so are the thermometer readings, except that the sleeping season of 1891 was decidedly warmer than that of 1894. There was also a surplusage of rain in the 1891 sleeping season; and in the growing season, half as much sun in 1891 as in 1894.

This may be tabulated as follows:—

	Growing Season. 1891.	Growing Season. 1894.	Sleeping Season. 1891.	Sleeping Season. 1894.
Rainfall	O	O	+	—
Sunshine	—	+	O	O
Temperature	O	O	+	—

The circles mean comparative equality; 1891 gets the plus marks for rain and temperature in the sleeping season, and 1894 the plus mark for sunshine in the growing season.

Perhaps this little table points out that rain is the most potent factor in the growth of evergreens; though, indeed, perhaps no proof of this is wanted. In the nine-year period, the evergreens achieve 51·5 per cent. of their growth in the growing season, and 48·5 per cent. in the sleeping season. Now the year 1891 shows a plus quantity of rain in the sleeping season, and the growth of evergreens that year occurred as follows:—

	Growing Season. Millimetres.	Sleeping Season. Millimetres.
2 Gum Trees	82	90
2 Pines	47	68
2 Blackwoods	43	42
	172 = 46·2 per cent.	200 = 53·8 per cent.

The only weather-factor in which 1894 is better than 1891 is sunshine in the growing season; and these trees in that year distributed their growth as follows:—

	Growing Season. Millimetres.	Sleeping Season. Millimetres.
2 Gum Trees	116	106
2 Pines	31	54
2 Blackwoods	47	22
	194 = 51·6 per cent.	182 = 48·4 per cent.

Can we come to the conclusion that though a plus amount of rain and temperature in the sleeping season of 1891 brought about what may be called an abnormal growth in the sleeping season, yet the plus amount of sunshine in the growing season of 1894 was sufficient to equalise the growth of the two years?

It seems doubtful. As previously noted, 1889 was the best year for growth, and had the heaviest rainfall and the least sunshine; and in 1893, the year of worst growth, the rainfall was but slightly deficient in both seasons, and there was a considerable excess of sunshine in the growing season. But no other weather-factor, of those now taken into consideration, appears to tend to equalise the tree-growth in these two years 1891 and 1894.

The years 1889, 1895, and 1898 each present an increase of growth on the three or four years immediately preceding them, and these years all have a plus rainfall as thus—

	Growing Season.			Sleeping Season.		
	1889.	1895.	1898.	1889.	1895.	1898.
Rain	+	+	+	+	+	+
Sunshine	—	—	—	—	+	—
Temperature	—	—	—	—	+	—

Though 1895 has plus sunshine and temperature in the sleeping season, as well as rain, its growth is not very much more than that of 1894, whose weather conditions do not seem to be much worse than those of 1893, already pilloried as the worst year for growth of the fourteen. It may be well to note that in the growing seasons of 1889 and 1895, the minima temperature means are a little over the average.

The year 1897, of worse growth than the three preceding and one following year, has all plus weather-factors in the

growing season, and all minus factors in the sleeping season; and the growths are as follows:—

	Growing Season. Millimetres.	Sleeping Season. Millimetres.
Gum Trees .	113	107
Pines . .	35	27
Blackwoods .	41	8
	189 = 57·1 per cent.	142 = 42·9 per cent.

It would seem that, save in the case of the Eucalypti, the evergreens depend much on the weather of the sleeping season.

Locusts did severe damage at the end of 1896 and the beginning of 1897; and these years shall be referred to later on.

Turning to the ten deciduous trees, the years 1890 and 1891 present a nearly identical growth; the deficiency of rainfall in the growing season of 1890 is greater than in the same season of 1891, and it has a larger excess of sunshine; but the temperature was lower, owing to the low minima readings. In the sleeping season, 1891 has a plus average of rainfall, a little over average sunshine, and a little over average temperature; whereas in 1890 the rainfall was deficient, the sunshine considerably in excess, and the temperature of minima readings below the average.

Now in the nine-year period, seven deciduous trees achieve 91·2 per cent. of their growth in the growing season, and 8·8 per cent. in the sleeping season; whereas in these years, 1890 and 1891, their growth in growing season 1890 is 86·6 per cent., and in 1891 it is 81·3 per cent.; and in sleeping seasons, 13·3 and 18·7 per cent. Only sunshine, apparently, can be credited with the over-average growth in 1890 sleeping season; and the more than double average growth in 1891 sleeping season must be due in various proportions to the plus average rain, plus average sunshine, and plus average temperature. It would almost seem as if a considerable excess of sunshine—the sole advantage of 1890—counterbalanced the extra good weather conditions of sleeping season 1891, and the average good conditions of its growing season.

	Growing Season.		Sleeping Season.	
	1890.	1891.	1890.	1891.
Oaks .	79	100	8	24
Paraisos .	38	20	9	15
Poplars .	56	71	5	3
Robinia .	9	14	3	4
	182 = 86·6 %	205 = 81·3 %	28 = 13·3 %	47 = 18·7 %

The years 1889, 1895, and 1898 were referred to when discussing the evergreens. Like the evergreens, the seven deciduous trees have an increased growth in these three years.

The worst year for evergreens was 1893, but 1892 is the worst for deciduous trees,—this year has already been mentioned as nearly as bad as 1893 for evergreens,—its rain deficiency is the greatest in fourteen years, it has more sunshine (especially in the sleeping season) than any other year, and its temperature—excepting the sleeping season minima—is above the average. This does not seem as if sunshine were of great value to tree-growth.

These speculations may be summed up as follows:—The best growths of evergreen and deciduous trees have always been accompanied by an over-average rainfall, and, with one exception, by deficiency of sunshine; in 1889 and 1898, with an under-average temperature; and in 1895, with an over-average temperature in the sleeping season. The worst growths always occur with a deficiency of rainfall, and, with one exception, an over-average of sunshine; also, an over-average temperature in the growing season, and an under-average temperature in the sleeping season.

As previously mentioned, locusts did much harm in the end of 1896 and the beginning of 1897; and this harm is indicated generally in the growth-curve diagrams for these two years, for I present, with these notes, diagrams showing the monthly growth of each species of trees for each of nine years; besides another diagram with the total average monthly growth-curves for the whole term, each diagram with notes of the weather for that particular year.

The diagram for 1896 shows how the Gum trees fell back in October; the Pines and Blackwoods suffering in November, and falling back in December; the Oaks, Paraisos, and Robinia showing but a slow growth; and the Poplars, little growth at all in the last three months of

1896. In the first three months of 1897, the Gums do not seem to have suffered at all from locusts, but Pines and Blackwoods evidently did. Oaks, Paraisos, and Poplars are almost stationary; and Robinia at first decreases, and then grows a little.

Thus part of the poor growth of 1896 and 1897 must be laid to the account of the locusts, and not all to weather.

I am informed that the locusts spared Melons, Cucumbers, Paraiso trees, and Cottonwoods (*Populus angulata*). This growth-curve diagram certainly shows that Paraisos sympathised with other trees during the locust invasion; and the Cottonwood also, at least in January and February 1897, when its growth was 1 millimetre against the nine-year January average of 9·4 millimetres, and −1 millimetre against the average 5·9 millimetres for February.

This was the worst invasion of locusts known in Uruguay since, if I remember rightly, the year 1856. I am told: "Not only have they eaten the leaves of the trees, with the exception of the two kinds, but also the bark of the topmost branches, even of the Orange trees; so much so, that the plantations look white." The water in the streams went bad with their dead bodies. The danger arising from this was fortunately removed by a cloud-burst, which flushed the streams.

In the "Notes on Tree Measurements" published in 1890, the decrease in growth at a certain season of deciduous trees was commented on at considerable length. Further experience fully confirms the remarks then made, but distributes the season of decreases over a longer space of time.

It is worthy of remark that during the first five of the fourteen years 1885–1898, the evergreens grew 2·942 millimetres, or 47 per cent. of their total growth for fourteen years; and 3·319 millimetres, or 53 per cent. of their total growth in the last nine years. But the seven deciduous trees grew in the first five year 3·276 millimetres, or 55·5 per cent.; and in the last nine, 2·627 millimetres, or 44·5 per cent. of the total growth for fourteen years. What might be called the "par" rate of growth, if weather-

factors had been equal in all years, and if older trees grew at the same rate as young ones, would be 35·7 per cent. for five years, and 64·3 per cent. for nine years.

The attempts I have made to ascertain the value of certain weather-factors in influencing tree-growth do not seem to prove anything in particular, except that rain is more essential than anything else; and this is borne out by a comparison of the weather of the five-year period with that of the nine-year period.

	Inches Rain.	Hours Sun.	Mean Temperature.
For the Five-year Period	48·82	2786	60°·4
For the Nine-year Period	42·01	3085	60°·6
For Eighteen Years, to December 1898	44·12	2960	60°·7

We need not suppose that the annual surplus of 6·8 inches of rain for the five-year period made all the difference between the growth of that and the nine-year period; for there can be little doubt that trees grow faster in their earlier than in their later years.

And it would seem that advancing age impedes the growth of deciduous trees more than it does that of evergreens.

Additional Notes on Andromeda Polifolia, Linn With Special Reference to Two New Stations. Also Remarks upon the Toxic Properties of Andromeda Polifolia, Linn., and other Members of the Ericaceæ. By Symington Grieve.

(Read 14th December 1899.)

Last January I read to this Society a paper entitled "Some Notes on *Andromeda polifolia*, Linn." It was then suggested that I should make some further investigations regarding the distribution of the plant in Liddesdale and Eskdale, and, if possible, find out if it was still growing on the Solway Moss, where Dr. Lightfoot collected it in 1772. Hence the following notes and observations.

On 31st January 1899, Dr. William Craig was good enough to inform me that he had heard from a gentleman that

A. polifolia grew on the moss behind the United Presbyterian Church at Chapel Knowe, a few miles from Canonbie, in Dumfriesshire.

On Wednesday, 31st May 1899, I drove with my wife from Kershopefoot, in Cumberland, to Chapel Knowe, *viâ* Canonbie. There is a moor with deep peat on the south-east side of the public road, and I discovered *A. polifolia* growing abundantly as soon as I reached the part of the moor where the peat was not removed for burning. I did not search as far as behind the United Presbyterian manse, as the plant was growing abundantly all over the moss wherever there was a thick deposit of peat, and I got as many specimens in flower as I required.

On 25th March 1899, I received a letter from Mr. Symers Macvicar, who drew my attention to *A. polifolia* having been recorded as having been found in the Island of Jura, in Walker's "Essays on Natural History and Rural Economy," published in 1812, pp. 248–251. The author of this work was the Rev. John Walker, D.D., Professor of Natural History in the University of Edinburgh. At p. 250 he writes: "It was found beginning to flower, the 27th of June, in the deep turf bogs of Jura, with its roots creeping for a great length in the *Sphagnum palustre*, Linn." It appears to me that it was probably nearly over flowering when seen by the Rev. Dr. Walker, instead of, as he states, beginning to flower.

In the "Annals of Scottish Natural History" for April 1899, at p. 121, Mr. Robert Godfrey mentions that he collected a single plant of *A. polifolia* in flower on 8th May 1895, on the Auchincorth Moss, which is near Penicuik. It seems unusual to find only one plant, as at the stations with which I am acquainted it is generally growing abundantly and scattered over considerable areas.

On 13th May 1899, I drove with my wife from Kershopefoot to a part of the hillroad to Langholm about four miles from Newcastleton, and on the way met Mr. John Elliot, who went with us. He pointed out the place where the *A. polifolia* grows most abundantly. We got the specimens just coming into flower. This station is in Roxburghshire.

My next visit to this station was on 27th May, when

driving to Langholm with Dr. Wm. Watson, Mrs. Watson, and my wife. We found the *A. polifolia* in flower in considerable abundance, and growing over a wide area of ground.

After crossing Tarras Water, we again left the waggonette and walked up the hill. Dr. Watson and I walked on, leaving the ladies to follow leisurely. When we reached the place where we were to rejoin the conveyance, about three miles from Langholm, we found we would have a few minutes to wait, so we examined a small part of the moor on the south side of the road, and I discovered *A. polifolia*, and pointed it out to Dr. Watson. We found at first only barren stems with foliage, and then a quantity in flower. It does not seem quite clear if this station has been known before, although the plant has been recorded from Eskdale, which is rather indefinite. This station is in Dumfriesshire.

On 30th May, I met Dr. Wm. Craig in Edinburgh, who informed me that *A. polifolia* was found growing abundantly on the moor near the road from Lochmaben to Templand. This is also in Dumfriesshire.

I was anxious to visit Solway Moss, about two miles from Longtown, in Cumberland, as it is a station mentioned by Dr. Lightfoot in his "Flora Scotica" for *A. polifolia*. Accompanied by my wife, I drove there from Kershopefoot, on Wednesday, 7th June, and spent about two hours botanising over a part of the moss from which no peats have yet been dug. We found the plant growing abundantly on level parts where the ground was moist, and generally among heather and sphagnum. The larger plants were found in the drier situations, but these plants had seldom young shoots, while most of the plants growing among sphagnum had many of these. We found growing along with it *Drosera anglica* and *D. rotundifolia*.

A large colony of black-headed gulls were breeding on the moor, but most of the eggs were hatched. We got few plants of *A. polifolia* in flower, as it was past the flowering time at this low elevation, which cannot be above 40 or 50 feet above sea-level.

It was with strange feelings I visited this station, as I am unaware of any record of *A. polifolia* having been found

there since 1772, when Dr. Lightfoot mentioned its existence at this place.

I had long had the opinion that *A. polifolia* was likely to be found in some parts of the wilds of Bewcastle, in Cumberland.

I had made a number of botanical excursions to the district without finding the plant, and it was only on Saturday, the 10th of June last, that I discovered it growing at an elevation of about 900 feet upon the highest part of a moor between Stelshaw Farm House and Black Lyne Valley, a short distance south of Skelton Pike.

The plants were growing on the flat part of the moss where the ground was wet. The specimens appeared to me less robust than those I had obtained at other places. This, as far as I know, is quite a new station for *A. polifolia*, and it grows over a considerable extent of moss, as what follows will prove. Continuing my walk, I went on to Christianbury Craig, its summit being 1598 feet above sea-level, *viâ* the Reamy Rigg, but found no more *A. polifolia* until, on my way home, I was recrossing another portion of the same moss where I had found it earlier in the day, when I came across the plant once more.

During this excursion I did not find a great variety of plants, but I do not remember ever seeing such a large extent of the Cloudberry, *Rubus chamæmorus*, in flower, as I found on the Reamy Rigg, and between that and Christianbury Craig. I also found plenty of the Crowberry, *Empetrum nigrum*, also the Cowberry, *Vaccinium Vitis-Idæa*.

I was much interested in finding *Listera cordata*, the heart-leaved Twayblade, in flower, growing in great abundance; sometimes many plants growing in close proximity to each other. This plant was growing on bare ground, from which the heather had been burnt off only two months previously. It is wonderful how its roots or seeds could resist the effect of the fire. I am also led to the conclusion that *L. cordata* is much more plentiful than most people suspect, growing among heather, among the foliage of which it is very much concealed. It is generally considered one of the less common plants in this district.

On Monday, the 26th June, I had the pleasure of the company of the Rev. Dr. Paul, our President, and during our walk we visited the Roxburghshire Station for *A. polifolia*, near the hillroad to Langholm from Newcastleton. We found the plant, but not in flower, as it was past flowering for the early part of the season.

Although we continued our walk for a considerable distance across the hills, we were not so fortunate as to discover any other place where *A. polifolia* grew.

On 5th August, I visited the Yad Flow, also in Roxburghshire, which evidently has derived its name from an old mare that had sunk in it. This station was discovered by Mr. John Elliot, as mentioned in my previous paper, but by mistake its elevation was given as 1000 feet, while it should have been 1250 feet. I found the *A. polifolia* growing abundantly, but not in flower. My next visit to this Flow was on 2nd October, when, accompanied by my son, we found many plants of *A. polifolia* in flower, but no fruit. On the same day we also visited the station near the road from Newcastleton to Langholm, and which I have already several times referred to, and there we found the *A. polifolia* with flower-buds, in full flower, and with young fruit. This was evidently the second time the plant had been flowering and fruiting this season.

In the flower border at Kershope House, Kershopefoot, the *A. polifolia* flowered, for the second time this season, about the 24th September, and went on flowering for about ten days.

I observed, at several places where the heather had been burnt this season, that the *A. polifolia* appeared to have been killed, probably owing to its lateral rootlets, running through the peat so near the surface, having been reached by the fire.

The record of Auchincorth Moss as a station is interesting, as it is probably the farthest east station on the eastern watershed of Scotland. The station in Jura which had been overlooked is also interesting, as it shows a great extension of the plant to the west of Scotland, and indicates it may yet be found at other places in the Hebrides, and perhaps also upon the western mainland of Scotland.

The Solway Moss at one time evidently covered a much larger area than it does now, and seems to extend even yet a considerable distance on both sides of the river Sark, which divides England from Scotland. It thus appears to me that the station at Chapel Knowe is really upon the Solway Moss, although on the Scottish side of the Border in Dumfriesshire.

Mr. Robert Godfrey, in his note about the Auchincorth specimen, at p. 121, "Annals of Scottish Natural History for 1899," quotes a letter of Mr. Wm. Evans, who, after referring to it as having been found growing on Blair-Drummond Moss and on Flanders Moss, says: "I have a note of its presence in the former of these localities down to 1882, and Mr. R. Kidston tells me it still grows in Flanders Moss, and also on a moss near Old Polmaise, a few miles on this side of Stirling."

In "Notes on the Fauna and Flora of the West of Scotland," p. 67, it is mentioned that *A. polifolia* is found at Garnkirk, Cadder Moss, and Paisley Moss.

I am indebted to Mr. Rutherford Hill for drawing my attention to a paper, by Mr. Robert Lindsay, on *Andromeda floribunda*, Pursh., or, *Pieris floribunda*, Benth. et Hook. f., and which appears at p. 333 vol. xix. of the "Transactions" of this Society. He gives several instances of sheep being poisoned, and of numbers dying through eating the plant, and also quotes the "Gardeners' Chronicle" of 20th April 1878 as his authority for the death of a horse from eating *A. floribunda.* The horse died in great agony in less than twenty-four hours. The contents of the stomach were examined, and found to consist of a small quantity of the shrub, and this mostly the flower-buds.

Dr. Cleghorn in the "Transactions" of this Society, vol. ix. p. 410, draws attention to a notice in the "Gardeners' Chronicle" of 17th March 1866, p. 256, where a case is mentioned where eighteen sheep died out of thirty-seven that showed symptoms of the poison, having eaten the plant during an invasion of some private grounds. After treatment, nineteen out of the thirty-seven recovered. *A. floribunda* was introduced into England from North America in 1811.

In the discussion that followed the reading of this paper,

Dr. Cleghorn mentioned that the shepherds of the Himalayas recognise the poisonous properties of *Pieris ovalifolia*, D. Don, especially when the leaves are in bud.

Mr. Rutherford Hill said: "That on seeing this paper of Mr. Lindsay's upon the billet" (referred to above), "he was reminded of some recent researches as to the poisonous constituent of Narcotic Ericaceæ, and had looked up some of the references. The first to separate the poisonous principle was Professor Eijkman, who, in 1883, obtained a glucoside from *Pieris Japonica* (*A. Japonica*), to which he gave the name of *asebotoxin.* This substance he found to be exceedingly powerful, the fatal dose for a rabbit being, ·003 gramme, or about one-twentieth of a grain, or an infusion of 2 grammes of the leaves ('Chem. Centralbl.,' 1883, p. 72). He also obtained a second glucoside, *asebotin*, which possessed a bitter taste, but was non-poisonous. The investigation was repeated by Professor P. C. Plugge in the following year. He obtained two substances from *P. Japonica* which proved to be identical with those separated by Eijkman. Plugge succeeded in getting the poisonous glucoside in fine silky needles, having the formula $C_{31}H_{51}O_{10}$. He gave it the name of *andromedotoxin*, by which it is now universally known. It possesses in a very high degree the physiological properties of the poisonous Ericaceæ. Within the last few years Professor Plugge and Herr Zaayer have examined a large number of ericaceous plants, and have found *andromedotoxin* in the following:—

"Leaves and Wood of Pieris Japonica, Benth. et Hook. f.
Do. Young Twigs of ANDROMEDA POLIFOLIA, Linn.
Do. do. A. polifolia angustifolia.
Do. do. Cassandra calyculata, Don.
Do. Flowers of Leucothoe spinulosa, Don.
Do. do. Azalea Indica, Linn.
Do. do. Rhododendron maximum, Linn.
Do. do. R. ponticum, Benth. et Hook. f.
Do. do. R. chrysanthum, Pall.
Do. do. R. hybridum.
Berries of Kalmia latifolia, Linn.
Leaves and Twigs of K. angustifolia, Linn.
Entire Herb of Monotropa uniflora, Linn.

"*Andromedotoxin* was found in largest quantity in the leaves of *Kalmia angustifolia*, which is known as 'Lamb-kill' in America. The same body probably exists in *Pieris Mariana*

(*A. Mariana*), which bears the significant name of 'Stagger-bush' in America. He had been led to take an interest in this matter because of a paper by Dr. Thresh (of Buxton) and Dr. Stockman (of Edinburgh) on the poisonous honey of Trebizonde, read before the Pharmaceutical Society a few years ago. An extract prepared from this honey was found to produce the characteristic symptoms of *andromedotoxin* poisoning. This was attributed to bees having visited plants of *Azalea pontica* and *Rhododendron ponticum*, which grew abundantly in the neighbourhood, but nothing definite was known as to the poisonous properties of either plant until the researches of Plugge and Zaayer pointed to *R. ponticum* as the probable source. This honey was interesting, as it was believed to be identical with the famous honey which proved so disastrous to Xenophon's army, and the symptoms recorded of that instance correspond closely with those produced by *andromedotoxin*. As showing the toxic effects of *R. ponticum*, it was stated that at Syndall Park, Laversham, eight sheep which ate the leaves of the plant were found dead next morning.

"Plugge and Zaayer did not seem to have examined *Pieris floribunda* (*A. floribunda*), but the general conclusion to which they came was that *andromedotoxin* was the poisonous constituent of all narcotic ericaceous plants."

It is certain that *andromedotoxin* is found in the young twigs of *A. polifolia*, and this discovery of Professor P. C. Plugge is described by him in his paper in "Archives der Pharmacie," Nov. 1883, pp. 813–819.

From the remarks made by Dr. Cleghorn it seems probable that the leaves are most poisonous when still in the bud.

It is quite evident therefore that whenever *A. polifolia* grows in situations where cattle, sheep, or horses can get at it, there is much danger of the animals being poisoned, and the deaths of many animals that have died from some mysterious cause may probably be accounted for by this plant having been eaten.

In the "Veterinary Journal," vol. xliii. p. 14, there is an interesting paper by Dr. R. Stewart MacDougall, on "Poisonous Plants of the Heath Family." In that communication he mentions that the leaves and young twigs of

A. polifolia are poisonous. He refers to a case where four ewes and a lamb which had strayed into a garden near Kendal were poisoned through eating *A. floribunda*. They showed signs of abdominal pain, accompanied with great difficulty in swallowing. The sheep were ill from twelve to fifteen hours, and only one ewe recovered.

Dr. MacDougall remarks: "That at home, owners of stock have always been suspicious of Rhododendrons, while, where they are native, their dangerous qualities when the plants are used as food have long been recognised. So too with the Andromeda." He gives a list of plants of the natural order Ericaceæ proved to contain *andromedotoxin*, and, as it differs in some respects from the list given by Mr. Rutherford Hill, I may be allowed to give it:—

"Andromeda Japonica.—Leaves and wood.
A. POLIFOLIA.—Leaves and young twigs.
A. Catesboli.
A. calyculata.—Leaves and young twigs.
Pieris formosa.
P. ovalifolia.—The late Dr. Cleghorn writes of this plant being well known to the shepherds of the Himalayas, where goats browsing on its young leaves have been poisoned. Its Indian name of blood-killer is interesting, as is also the observation that its leaves used as a litter act as an insecticide in the cattle stalls. Its honey also is poisonous.
Kalmia latifolia and K. angustifolia, 'the latter known popularly as lamb-kill.'
Rhododendron ponticum.—Sheep have been known to die the day after eating its leaves. Its honey is also poisonous.
R. Falconeri.
R. grande.
R. barbatum.
R. fulgus.
R. punicum.
R. chrysanthum.
R. hybridum.
R. maximum.—Leaves and flowers.
R. cinnabarinum.—Its leaves are poisonous, and if the plant be burned the eyes smart and the face swells.
Azalea Indica.—Leaves and flowers.
Monotropa uniflora.—Parasitic on the roots of other plants. Entire plant poisonous.

"Other plants of the order which, as far as I have been able to find out, have not yet been investigated, but are known practically as dangerous plants are—

"Andromeda Mariana.—The stagger-bush.
Rhododendron arboricum.—This poisonous rhododendron is a native of India, but has been grown in the Edinburgh Royal Botanic Garden. According to Watt, the natives

of India sometimes eat its flowers, which have a sweet acid taste, and eaten in quantities cause intoxication. This species produces a great deal of poisonous honey.

R. Anthopogon.—Another Indian form, growing in the high mountain passes, its resinous odour causing headache to travellers over the passes. Even when the plant is dried and in a herbarium the odour is unpleasant."

But to return to the consideration of *A. polifolia*. Seeing it was desirable to find out if any deaths occurred among the sheep or cattle pastured on land where *A. polifolia* was known to grow, I wrote one of the most extensive farmers on the Borders, asking him if any unusual death-rate had occurred among his sheep pastured upon a particular area of ground on which I knew the plant was abundant. He replied that he had lost a large number of sheep upon the land indicated. Those sheep were put on the land at different times, and they all took what is known as "louping-ill," or trembling. Sheep bred on the same land are also subject to this disease, but not to the same extent as sheep newly put on. Last June (1899) a post-mortem examination was made on three or four, but all the veterinary surgeon could say about them was that they had died from inflammation.

There is no death, excepting in the spring months, amongst the ordinary stock, but when strange sheep are brought on during spring or summer months they are almost sure to be affected about ten days after coming on the land.

In October 1898, he put some ewes on the land, and they were free from disease until the April following.

In a later letter the same gentleman informs me that last June (1899) he put blackfaced ewe hoggs on the land, and as louping-ill was so bad amongst them he removed them all to the grass fields near the farmhouse. After some time the trouble ceased and the sheep improved, so that he had them removed to other fields. After they were all removed from the fields mentioned, where several had died, and all had louping-ill more or less, he put on some ewes, lambs, and calves. Several, both ewes, lambs, and two calves, took louping-ill. There were no cases in those fields before, and after about six weeks from the time the hill hoggs left, no other sheep or lambs put into the fields mentioned had disease of any kind.

My correspondent also informs me that from other

information he thinks it possible that sheep suffering from louping-ill may infect other land to which they are removed, but the infection is only of a temporary nature, as after a lapse of time sheep put on to such land do not suffer.

This information is very interesting, and naturally suggests some form of poisoning: and as *A. polifolia* is the only poisonous plant we know of upon the land in question, attention is at once drawn to it.

Louping-ill is a mysterious disease, which has been attributed to *ergot*, and also several other forms of vegetation; but it is quite possible it is only the symptoms caused in sheep or cattle by certain forms of poisoning, of which *andromedotoxin* may be one.

As to the infection of grass fields by sheep that have been removed to them suffering from louping-ill, it is possible it may be discovered that a bacillus in the sheep absorbs the poison, and, passing out of the animal with its evacuations, finds its way to the grass, on which it remains for a time, until it either dies or gets rid of the poison. If other sheep are put on to the pasture before the bacilli become innoxious, they may be poisoned, and in all probability have the symptoms of louping-ill. Further investigation will be necessary before any definite conclusion can be formed as to this, but those in a position to experiment should soon be able to settle the question.

I may conclude by remarking that *A. polifolia* is found growing most abundantly on flat, peaty mosses, where there is poor drainage. On sloping ground, it grows sparsely. It is generally found growing along with heather, and often among sphagnum. Where peat has been recently dug, or where peat only forms a thin covering to the soil, *A. polifolia* does not appear to grow naturally; yet it may be transplanted into a garden and grow well, especially if the situation is damp; if the situation be dry, it may live, but does not seem to thrive, and the foliage of the plant becomes darker. At least that has been my experience.

The plant buds generally twice each season, and as the budding time appears to be the period during which the plant is most poisonous, sheep, cattle, and horses should be kept off the ground on which it grows during April, May, and the greater part of June. During July and the first

half of August, there appears to be less danger to beasts from eating the plant; but this is not to be depended on, as the leaves and twigs possess powerful toxic properties. From the middle of August until the middle of October the second period of budding takes place, and during this time great caution must be exercised. From the middle of October until the following April the plant does not seem to possess such powerful poisonous properties, and, as far as my investigations have gone, sheep appear to browse upon the ground where *A. polifolia* grows without suffering any harm.

Dr. R. Stewart MacDougall, in the paper I have already referred to, mentions that "no chemical antidote is known for *andromedotoxin*."

This leads one to infer that cases may be difficult to treat medicinally, and that, at least, prevention is better than cure.

As to the potency of the poison, some conception may be formed if it is remembered that two grammes of the leaves of *A. Japonica* killed a rabbit; and, probably, *andromedotoxin* is present in *A. polifolia* in equal quantity, and will act with equal effect. It may aid the mind in grasping what the power of such poison really means if I point out that two grammes is equal only to 30·8880 grains, and, as each pound avoirdupois contains 7000 grains, such a quantity is sufficient to poison 226 rabbits.

Some of the symptoms of *andromedotoxin* poisoning appear to be derangement of the nervous system; abdominal pain, probably from acute inflammation; great difficulty in swallowing. Some animals suffer intense agony. The poison acts quickly, and sometimes death takes place in a few hours, but more frequently in about twenty-four hours. If the animal survives for a period of thirty-six hours after eating the plant, there is generally some hope of recovery. After three or four days, the animal generally has recovered.

Having referred to the poisonous effects of *A. polifolia*, it may be as well to give one quotation as to what is said about the virtues of the plant. In Gray's supplement to the "Pharmacopœia," second edition, 1848, p. 362, it is mentioned that *A. polifolia* is used in fomentations and baths against rheumatism and paralytic affections, causing perspiration. It dyes a fine yellow, and tans leather.

EXCURSION OF THE SCOTTISH ALPINE BOTANICAL CLUB TO KIRKBY-LONSDALE in 1899. By WILLIAM CRAIG, M.D., F.R.S.E., F.R.C.S.Ed., Secretary of the Club.

(Read 11th January 1900.)

On Monday, 31st July 1899, the following members of the Scottish Alpine Botanical Club met in the Royal Hotel, Kirkby-Lonsdale :—William B. Boyd, President: Rev. Dr. David Paul, Rev. George Alison, Rev. George Gunn, Dr. David T. Playfair, P. Neill Fraser, George H. Potts, A. H. Evans, and Dr. William Craig. The Club on this occasion had as visitors—Mr. George Stabler, a well-known authority on mosses; R. Turnbull, B.Sc.; James A. Terras, B.Sc.: F. C. Crawford, and H. R. Hall. Through the kindness of the Caledonian and London and North-Western Railway Companies, a fine saloon carriage was sent from Edinburgh to Kirkby-Lonsdale for the private use of the members of the Club.

Kirkby-Lonsdale is a fine old English town, pleasantly situated on the right bank of the Lune. The town is in Westmoreland, but is close on the borders of Yorkshire and Lancashire. The Club visited this place in 1884, but only for a single day.

On Tuesday, 1st August, our excursion was to Ingleborough Hill, a mountain 2373 feet high, and one of the highest in Yorkshire, and the White Scars, the summit of which is 1354 feet above sea-level. We drove in a conveyance as far as Ingleton, distant nine miles from Kirkby-Lonsdale. Here we left our conveyance and followed a rude cart-track as far as Crina Bottom, a small cottage fully two miles from Ingleton, and where non-intoxicating beverages may be had by the many travellers who pass on their way to Ingleborough Hill. The day was hot in the extreme, and as there was no wind, with a cloudless sky and a burning sun overhead, botanising was performed under the greatest difficulties. At this cottage the party divided into two divisions, one party proceeding to Ingleborough Hill—some of whom reached the summit,—the other party turned to the left and examined the rocks known as the White Scars.

Ingleborough Hill was rather disappointing from a botanist's point of view. Among the plants collected may be mentioned:—*Arenaria verna*, Linn.; *Saxifraga oppositifolia*, Linn.; *S. aizoides*, Linn.; *S. hypnoides*, Linn.; *Sedum Rhodiola*, DC.; *Cryptogramma crispa*, Br.; *Lycopodium clavatum*, Linn.; *L. alpinum*, Linn.; *L. Selago*, Linn.; *Selaginella selaginoides*, Gray; and the rare moss, *Orthothecium intricatum*, Hartm. This moss was gathered by Mr. Stabler.

The hill known as the White Scars is of a very peculiar formation of limestone, the stone lying in wavy beds, and forming deep fissures, in which many good plants were found. As seen from a distance it looks a most barren region, as little vegetation is visible above the tops of these deep fissures. In these fissures, however, many good plants were observed, including—*Thalictrum*, two species or varieties were observed, but as none of them were in flower, the species could not be accurately determined, but probably both were varieties of *T. minus*, Linn.; *Anemone nemorosa*, Linn.; *Actæa spicata*, Linn. (beautiful specimens on the north part of the Scars); *Arenaria verna*, Linn.; *Cratægus Oxyacantha*, Linn.; *Ribes Grossularia*, Linn.; *R. nigrum*, Linn. (the last three species apparently truly wild); *Sanicula europæa*, Linn.; *Adoxa Moschatellina*, Linn.; *Stachys sylvatica*, Linn.; *Carlina vulgaris*, Linn., in considerable abundance; *Hieracium*, various species; *Lactuca muralis*, Fresen.; *Mercurialis perennis*, Linn., very abundant in the deep limestone fissures; *Corylus Avellana*, Linn.; *Listera ovata*, Br.; *Polygonatum officinale*, All.; *Convallaria majalis*, Linn.; *Allium ursinum*, Linn.; *Scilla nutans*, Sm.; *Paris quadrifolia*, Linn.; *Arum maculatum*, Linn.; *Sesleria cærulea*, Scop.; *Molina cærulea*, Mœnch.; *Asplenium Ruta-muraria*, Linn.; *A. Trichomanes*, Linn.; *A. viride*, Huds.; *Scolopendrium vulgare*, Sm.; *Aspidium aculeatum*, Sw.; *A. lobatum*, Sw.; *Nephrodium rigidum*, Desv.; *Polypodium calcareum*, Sm.; *Lycopodium clavatum*, Linn.; *L. alpinum*, *L. Selago*, Linn.

With one or two rare exceptions these plants were found growing in the deep fissures of this remarkable limestone hill. Both parties met in the afternoon at

Crina Bottom, and after refreshments of tea and other non-intoxicating beverages, we walked back to Ingleton, where we found our conveyance awaiting us, and, after a pleasant drive home, we reached Kirkby-Lonsdale in good time for dinner, and though we were all more or less exhausted from the excessive heat of the day, yet we were all able to do ample justice to the good things of mine host of the hotel.

Wednesday, 2nd August.—The excursion to-day was to Farleton Fell, and Hutton Roof Crag. The rocks here were very similar to those of the White Scars, and many of the plants were the same as found yesterday. The day was again very sultry and extremely warm. We drove in a conveyance as far as the north side of Farleton Fell, and after a very stiff climb reached the summit and walked along the ridge to Hutton Roof. Farleton Fell is 800 feet above sea-level, whilst Hutton Roof Crag is 859 feet high.

Among the plants collected may be mentioned:—*Arabis hirsuta*, Br.; *Arenaria verna*, Linn.; *Potentilla Fragariastrum*, Ehrh.; *Viburnum Opulus*, Linn.; *Asperula cynanchica*, Linn.; *Scabiosa Columbaria* Linn.; *Primula farinosa*, Linn.; *Juniperus communis*, Linn.; *Taxus baccata*, Linn.; *Epipactis media*, Fries.; *E. violacea*, Bor. (?); *E. atro-rubens*, Hoffm.; *Polygonatum officinale*, All.; *Convallaria majalis*, Linn.; *Allium ursinum*, Linn.; *Scolopendrium vulgare*, Sm., many of the specimens with beautifully forked fronds, called by the natives "Fish-tails"; *Cystopteris fragilis*, Bernh.; *Nephrodium rigidum*, Desv., several specimens with forked fronds; *Polypodium calcareum*, Sm., very abundant in several places.

At Hutton Roof the conveyance met us in the afternoon, and we had a pleasant drive back to Kirkby-Lonsdale, although all were more or less exhausted by the extreme heat of the day.

Thursday, 3rd August.—The excursion to-day was to Sedbergh, in Yorkshire. The members went by train to Sedbergh and walked back to Middleton Station, and thence home by railway. Near Sedbergh, in a hedge on the side of the road, we saw one plant of *Ribes alpinum*, Linn. This is a station for this rare plant well known to

local botanists, one of whom directed us to the place. The plant, though rare, is a native of the north of England, but the specimen observed by us, being in a hedge and near a house, shows that it may have been introduced.

The Club botanised principally by the banks of the river Lune, and on Middleton Common. On the latter place both *Primula farinosa*, Linn.; and *Genista tinctoria*, Linn., were in great abundance. Among the plants observed may be mentioned—*Trollius europæus*, Linn.; *Saponaria officinalis*, Linn.; *Hypericum humifusum*, Linn.; *Genista tinctoria*, Linn.; *Prunus Padus*, Linn., in fruit; *Rubus saxatilis*, Linn.; *Ribes alpinum*, Linn.; *Œnanthe crocata*, Linn.; *Galium boreale*, Linn.; *Scabiosa Columbaria*, Linn.; *Campanula latifolia*, Linn.; *Vaccinium Oxycoccus*, Linn.; *Primula farinosa*, Linn.; *Lysimachia nemorum*, Linn.; *L. Nummularia*, Linn.; *Anagallis arvensis*, Linn.; *Plantago media*, Linn.; *Mimulus luteus*, Linn.; *Melampyrum sylvaticum*, Linn.; *Potamogeton densus*, Linn.; *Carex muricata*, Linn.; *C. remota*, Linn.; *C. Goodenovii*, Gay; *C. flava*, Linn., var. *Œderi*, Ehrh.; *Brachypodium sylvaticum*, R. and S.; *B. pinnatum*, Beauv.

At Middleton we got the train to Kirkby-Lonsdale. The day was again very hot, but we were often under the shade of the trees, and always by the bank of the river, and consequently did not feel so exhausted as on the two previous days.

Friday, 4th August.—The morning was again fine and the day very warm. Several of the party went to Ease Gill, about eight or ten miles to the north-east of Kirkby-Lonsdale, and dividing Westmoreland from Lancashire. Among the plants observed may be mentioned—*Draba incana*, Linn.; *Malva moschata*, Linn.; *Lysimachia nemorum*, Linn.; *Tamus communis*, Linn. Others of the members botanised Casterton Woods, on the left bank of the Lune, and observed amongst other plants—*Geranium phæum*, Linn.; *Prunus Padus*, Linn., in fruit; *Saxifraga tridactylites*, Linn.; *Symphytum officinale*, Linn.; *Paris quadrifolia*, Linn., two specimens with *five* leaves; *Bromus giganteus*, Linn.

It is worthy of note that *Tamus communis*, Linn., was very common in the woods and hedges around Kirkby-

Lonsdale. It is popularly known as "Black Bryony," a plant not found in Scotland. Another well-marked characteristic of the locality was the large amount of *Campanula latifolia*, Linn., and *Campula Trachelium*, Linn., the latter being much the more common plant, growing to a great size, and the flowers varying in colour from pure white to a deep blue—some of them were purple.

Saturday, 5th August.—The meetings of the Club for this excursion came to an end, and the railway companies provided a fine saloon carriage to bring the members to Edinburgh, and thus ended a most pleasant and a not unproductive excursion.

The Scottish Alpine Botanical Club was founded in 1870, and during the thirty years of its existence, with the exception of 1871 (the year of the meeting of the British Association in Edinburgh), the Club has made annual excursions in July or August, and, in addition, once in October and twice in April. With four exceptions all the excursions have been to the Scottish Highlands, the exceptions being—Teesdale, in 1884; Norway, in 1887; Connemara, in 1890; and Kirkby-Lonsdale, in 1899.

These annual excursions have afforded much happiness and pleasant intercourse to the members of the Club, and, in addition, have contributed not a little to our knowledge of the flora of Scotland and other countries.

Among the most notable discoveries made by the Club during these excursions may be mentioned the discovery of *Gentiana nivalis*, Linn., in Chamacreag, by Professor Bayley Balfour, on 3rd October 1879; the discovery of *Carex frigida*, Allioni (a plant new to the British Isles), in Corrie Ceann-mor, and of *Salix Sadleri*, Syme (a plant new to science), both plants being discovered in the same corrie by the late John Sadler on 7th August 1874. On 31st July 1880, the Club discovered a new station for *Thlaspi alpestre*, Linn., in Glen Taitneach, near Spittal of Glenshee. It was during the excursion of the Club to Braemar in 1883 that Mr. Boyd gathered that remarkable *Sagina* which bears his name. On 4th August 1885, I gathered on Beinn Laoigh three plants of *Aspidium Lonchitis*, Sw., with every frond crested; and from the

spores of these plants Mr. Boyd, of Faldonside, succeeded in raising very many seedlings, with all the fronds beautifully crested. During an excursion of the Club to Glen Spean in 1886, Mr. Boyd discovered a new station for that rarest of Scottish plants, *Saxifraga cæspitosa*, Linn. During the same excursion the Club discovered two new stations for *S. rivularis*, Linn., and one for *Luzula arcuata*, Swartz. During the excursion of the Club to Connemara, Dr. Stuart discovered the heath (*Erica Stuarti*) which bears his name, a variety never previously described. On 22nd July 1892, Dr. Paul discovered on Ben Lawers *Carex ustulata*, Wahl., and thus confirmed the original discovery of this plant on Ben Lawers by Don in 1810. This is one of the most interesting discoveries of the Club. Amongst other discoveries by the members of the Club may be mentioned the fact that I discovered in 1874 *Myosotis alpestris*, Schmidt, in Cam Chreag. During the excursion of the Club to Ben Nevis in 1876, and again during the excursion of the Club to Spittal of Glenshee in 1880, the Club discovered a remarkable form of *Saxifraga stellaris*, Linn., of which the late John Sadler thus wrote: "The most remarkable plant of all was a form of *S. stellaris*, which grew in large mossy-looking patches, resembling *Montia fontana*, the leaves being as small, the branches as delicate, and the flowers nearly as tiny as those of that plant." In 1881, during an excursion of the Club to Dalwhinnie, Mr. Potts discovered the variety of *Saxifraga aizoides*, Linn., known as *aurantiaca*. During an excursion of the Club to Teesdale in 1884, the late Professor Dickson gathered the white variety of *Gentiana verna*, Linn. During an excursion of the Club to Killin in 1885, I rediscovered the original station on Ben Lawers for *Cystopteris montana*, Link. In 1892, on Creag-na-Caillich, Mr. Boyd gathered *Carex rupestris*, Br., a new station for this plant. During this same excursion, Dr. Stuart gathered "a lovely rose-pink form of *Veronica saxatilis*, Linn., with a deep ring of crimson round the base of the corolla." In 1894, during an excursion of the Club to Tyndrum, the Club discovered on Beinn Laoigh a new station for *Kobresia caricina*, Willd.,

and on Ben Voirlich, near Ardlui, the Club observed a large quantity of *Pteris aquilina*, Linn., with fronds all crested. There would be at least an acre of the hillside covered with this fern, and nearly every plant was abnormal. In 1891, and again in 1894, and more especially in 1895, the Club gathered a large quantity of a submerged plant in Lochan Bhe, near Tyndrum. Excellent specimens were obtained, and submitted to eminent botanists, and there was a general concensus of opinion that the plant was *Scirpus fluitans*, Linn. No specimen was found with flower or fruit, and notwithstanding the opinion of eminent botanists, several members of the Club are not convinced that it is *S. fluitans*, and some favour the idea that it is a modified *Juncus*.

On 13th July 1899, three members of the Club, Mr. Boyd, Dr. Paul, and Mr. Lindsay, visited Ben Avon, a high mountain dividing Banffshire from Aberdeenshire, and gathered many interesting alpine plants, including *Saxifraga cæspitosa*, Linn. The plants were in full flower, but none were seen in seed. This is a very interesting find. The plant was discovered by Dr. Paul, and afterwards picked by Mr. Boyd and Mr. Lindsay.

This Saxifrage is one of the rarest of British alpines. Hooker, in 1821, possessed specimens gathered by G. Don. In 1830, Mr. William M'Nab gathered a single specimen on Beinn a' Bhuird, and it has never been found on this mountain since. In August 1831, Mr. W. Stables gathered it on Ben Avon. In the same year, but probably after August, Mr. John Mackenzie, gardener, Invercauld, gathered it on Ben Avon. Mr. Mackenzie was accompanied by Dr. Martin Barry, who also picked the plant. Dr. Barry, in 1832, again gathered the plant on Ben Avon, and there is no record of the plant having been gathered on Ben Avon since 1832, till Dr. Paul found it in July last. It appears to have been gathered on Ben Nevis by Joseph Woods before 1838, and since that time it was not recorded from Britain till Mr. Boyd discovered it in Glen Spean in 1886.

The discovery of this plant on Ben Avon by Dr. Paul, in July last, is a most interesting find. I have no means

of ascertaining whether the place discovered by Dr. Paul is the same as the station or stations recorded by Mr. Stables, Mr. Mackenzie, and Dr. Martin Barry.

Of the four British stations recorded for this plant, two, Ben Nevis and Beinn a' Bhuird, are unknown to any botanist; the other two stations are known—Glen Spean, discovered by the Club in 1886, and Ben Avon, rediscovered by members of the Club in July 1899.

OBITUARY NOTICE OF REV. GEORGE GUNN, M.A., Minister of Stichill and Hume. By Rev. DAVID PAUL, M.A., LL.D.

(Read 8th February 1900.)

On the 12th of January last the Rev. George Gunn, M.A., died in the house of his brother, Dr. Clement Gunn, at Peebles. He had been a member of the Botanical Society for seven years, and latterly acted as its Local Secretary in the Kelso district. For some months before his death his health had not been good; an obscure form of disorder had laid hold of him, but none of his friends supposed that it was very serious, much less that it would prove fatal. As late as the end of October he was able to do all his parish work, and to follow his usual pursuits without much apparent diminution of energy, so that none but those who were most intimate with him were prepared for the announcement that he had passed away. The tidings affected all who knew him, with a sense of keen personal loss; and there are many in this Society who mourn for him as a bright, intelligent, warm-hearted, and constant friend.

Mr. Gunn was born in Edinburgh in 1861, his father being sub-editor of the "Edinburgh Courant." He was educated at the High School and University here, and was licensed in 1876 as a probationer of the Church of Scotland. He served for a time as assistant to Dr. Norman Macleod, of St. Stephen's Church, in Edinburgh, and early in 1878 he was elected minister of Stichill,

a beautiful country parish three miles north of Kelso, and there he spent the remaining twenty-two years of his life. The record of that time is one of conscientious discharge of duty. He proved himself a model parish minister; he was the friend of all his parishioners, high and low, and they regarded him with the sincerest respect and affection. It is not too much to say that seldom has a parish minister been more truly mourned for by his people.

But far beyond the bounds of his parish his friendship was prized by a large circle. He was a singularly friendly man, and he had the faculty of making friends wherever he went. There was an attraction about him which it is not easy to define, but which was based on his good sense and humour, unselfishness, honesty of character and sympathy, and a lovableness which it was impossible to resist. While he added to his friends every year, he never lost one of them, for not only was he very careful of the feelings of others, but he was not a man of changeful moods—at times hearty, and at times cold. You felt you could depend upon him—he was always the same, one you could rely upon and trust. This was one of the most marked features of his character, as all who knew him will be ready to testify. Nothing pleased him better than to be in a position to assist another in any way, and he would put himself to more trouble for others than he would care to do for himself. Few men have been more popular among their acquaintances, but he did not court popularity,—it came to him unsought, as the result of the genuine and sterling qualities of his own character.

He had never received any proper scientific education, but from the time of his going to Stichill he began to use his leisure hours in acquiring all the information he could on the three subjects that interested him most—botany, geology, and archæology. Of his connection with the two latter sciences it is not necessary to say much here. His knowledge of geology was considerable, especially of mineralogy, and he had a very interesting collection of stones and minerals, all carefully classified and named. Along with his friend and former pupil,

Mr. Barron, at present engaged in a geological survey of the Mount Sinai district, he rearranged all the geological specimens in the Kelso Museum, which were before in a confused state, and unfit for any educative purpose. In archæology also he had made good progress. He studied the remains of prehistoric life in Scotland, and was something of an authority in connection with that subject. Anything old had a fascination for him, and he had gathered together many interesting relics. He loved to investigate old Scotch ways and customs, or to work out from ancient documents the history of a ruined building like the old Castle of Hume in his own parish. But it was perhaps to botany that he dedicated most of his spare time. He was a good field botanist, and it was mainly field botany that attracted him. He was a member not only of this Society, but of the Scottish Alpine Botanical Club, and of the Cryptogamic Society of Scotland. His knowledge of the wild flowers of Scotland was extensive, and he delighted in a botanical ramble which might add something new to his list. In 1898 he accompanied two of his friends to the Southern Tyrol, and the new flora opened out to him there was a source of intense pleasure to him. One of the most interesting communications recently made to this Society was an account of that expedition, read by him in April last. In his manse garden at Stichill he found an unfailing source of interest in the cultivation of a large number of plants which he had collected from many quarters, and he had a special love of Alpines, which he grew in his rockeries with great success. A new fernery had just been finished by him before he left his manse for ever. He possessed also a good herbarium, to which he was always making additions. He had acquired the herbarium of the late Mr. Andrew Brotherston, of Kelso, a collection valuable especially for its willows and roses, but, unfortunately, a portion of it was injured by fire after it came into his hands. From every expedition he returned with new specimens to add to his store. He would not have pretended to much knowledge of scientific botany, but he was one of those botanists who love and study wild plants, and who, in different parts of the country, have

done so much to keep alive and extend an interest in our native flora.

In his own district Mr. Gunn was best known as the Secretary of the large and prosperous Berwickshire Naturalists' Club, the oldest Field Club in Britain. His predecessor in that office, the late Dr. James Hardy, of Old Cambus, was a man of exceptional ability and scientific knowledge, and it shows the esteem in which Mr. Gunn was held that he was chosen to succeed him. His duties required for their successful discharge great tact and judgment in dealing with men, as well as knowledge of the many different branches of science which the Club pursues, and they entailed much labour and incessant correspondence. Without encroaching upon his parish work, he found time to undertake these, and to perform them to the perfect satisfaction of the Club. Dr. Hardy had brought the "Proceedings," which are published annually, to a high pitch of excellence, and Mr. Gunn devoted himself enthusiastically to maintaining the standard they had reached. In a very short time he worked off the arrears that had accumulated, and issued one part after another until he had brought them up to date. He not only wrote for and edited the "Proceedings," but the onerous task devolved on him of making all arrangements for the six meetings which are held every year in Roxburghshire, Berwickshire, and Northumberland. He thus came into contact with all who are interested in science in these counties, and the more he became known the more he was respected and liked. In the various expeditions of the Club, as in those of the Scottish Alpine Botanical Club, he was a charming companion, genial, warm-hearted, good-tempered, and amusing, and none will miss him more than the members of these two clubs, whose meetings he was never absent from. If he had been spared he would have done much more useful work than he had the opportunity of doing. He was cut off in the prime of his life and vigour, and has left behind him, enshrined in the hearts of his many friends, the memory of a good man, and of an unselfish, laborious, useful life.

NOTES ON A VISIT TO THE DOVREFJELD, NORWAY, IN JULY AND AUGUST 1899. By JOHN MONTGOMERIE BELL, W.S.

(Read 8th February 1900.)

Having been interested in the flowers of Norway on previous visits, and having learned that the Dovrefjeld was the best botanical ground in that country, I arranged to visit that district last summer along with Mr. Alexander Cowan, of Penicuik, a well-known collector of plants.

The Dovrefjeld is a large mountainous district, separating southern from northern Norway. It may be reached either from Trondhjem, on the north-west, or from Christiania, on the south-east, as well as in other ways. Our plan was to reach it from Trondhjem, and to work through it till we reached the railway to Christiania. We sailed from Grangemouth on 12th July in the s.s. "Norway" for Ekersund, at the south-western extremity of Norway, with tickets enabling us to return from Christiania. After a tolerable voyage—the North Sea is seldom more than tolerable—we landed at Ekersund early in the morning of the 14th, and proceeded by rail to Stavanger, a run of two and a half hours. The route lay chiefly along the sea-coast, and the flora, as seen from the train, seemed similar to what we have at home, except that we observed *Arnica montana* growing in the meadows, and the blue lupin (*Lupinus angustifolius*), neither of which did we meet with again.

From Stavanger, next day, we had a beautiful sail in sheltered waters to Bergen. This old town is picturesquely situated on a hilly peninsula overlooking the sea, with steep lofty mountains in the immediate background. We had only time for a drive to various points of interest, including the large villa belonging to the composer Edouard Grieg, as we had to sail the same night by another steamer for Trondhjem, which was reached at 2 A.M. on the 17th. In passing Molde we saw the German Emperor's yacht, the "Hohenzollern," lying at anchor. Trondhjem, a town of thirty thousand inhabitants, which was founded about a thousand years ago, and in which the Kings of Sweden and Norway

are still crowned, is the most northerly of the large towns of Europe, being in the same latitude as the south coast of Iceland (63° 30′ N.). As we approached it from the south, sailing up the Trondhjem Fjord, we met the steamers which had just started with passengers for the North Cape, to see the midnight sun. We did not spend any time here, however, on this occasion, as we were invited to visit a friend who had a salmon fishing on the Namsen River, one hundred miles farther north, and we expected to have another opportunity of seeing Trondhjem on our return. Taking steamer in the afternoon for Namsos, a small town near the mouth of the Namsen River, we reached our destination in the small hours of the morning, this being the third time within a week that we had to disembark from a steamer and seek beds at an inn in the middle of the night, a somewhat fatiguing experience. There was a leper on board the steamer, a young man who had been discharged from hospital at Trondhjem as incurable, and was going home to his parents. There are leper hospitals in all the large towns in Norway, but the disease is said to be on the decrease, consumption being on the increase in that country. Leprosy in Norway has been attributed to the prevailing diet of the peasantry, which consists of dried fish, to the exclusion of green vegetables.

The sound of the hammer was very rife at Namsos, for, like many other towns in Norway built of wood, it is being rebuilt after a fire, and that not for the first time. Visitors from this country should make the acquaintance of Mr. Sommerschield, the Vice-Consul here, who is very obliging, and something of a "character." It is said that his greatest distress after the late fire was at the loss of "Webster's Dictionary" and "Burke's Peerage," apparently his most invaluable companions.

The next stage of our journey was a twenty miles drive in cariols up the wide valley of the Namsen to Oberhalden, above which the river is no longer tidal. At this beautiful spot we spent nearly a week, resting after our long steamer journeys; and, although salmon fishing was the order of the day as well as of the night, we were able to make a few notes on the botany of a fertile lowland and sub-alpine country.

The Namsen River is one of the best in Norway for salmon. The fishing is by trolling, or "harling," with minnow from a boat. An expedition to the river was usually made in the forenoon, returning about three o'clock for dinner and repose, going out again at six or later, and coming home about midnight. A good many fish were caught on each excursion, often of good size,—even the botanists, inexperienced in this form of the gentle art, landed (among others) two fish, one a little over, and the other a little under, thirty pounds.

One of the industries of the place (it was a large farm, worked by the proprietor) is hay-making, which we saw in full swing. They have their own way of doing it here. As the grass is being cut, they stick into the ground long rows of poles, like hop sticks, a few yards apart, from end to end of the field; then tie cords to the poles, and hang the grass thereon to dry. It looks as if rows of long green hedges had grown up under your windows in the course of a few hours. They say that the hay is dried much sooner in this way, as the air gets through the interior of the "hedge," in addition to the action of the sun and air outside,—and this is probably true; but we saw an instance of one drawback to the system, where a gale of wind had laid the whole erection flat on the ground.

The first sight of a Norwegian wood is something of a revelation to the British botanist. The profusion and luxuriance of the vegetation, and the rich variety of the flowers with which the ground is carpeted, many of these being new to the traveller, are quite dazzling to the eyes until one gets used to the novelty. The woods are chiefly pine, but in places the birch, oak, beech, and elm abound. It may be remarked in passing that the leaves of some of the trees in the northern parts of Norway develop to an enormous size, a fact attributed to the long light in the summer months. The undergrowth of flowers through which one has to wade in going through the wood is made up of *Vaccinium* in all species; *Linnæa borealis*, the lovely evergreen creeper, presenting itself in graceful ways of endless variety; *Cornus suecica*, a black and white object amid a mass of green; several species of *Pyrola*, *Rubus saxatilis*, *Lycopodium annotinum*, *L. clavatum*, *L. Selago*, *Polypodium*

Dryopteris, *P. Phegopteris*, *Maianthemum Convallaria*, etc.

During our stay at the Namsen River, the following were also observed :— *Trientalis Europæa*, *Mulgedium alpinum* (this plant is said to be used medicinally by the Lapps, who mix it with their bread, as a preventive of scurvy), and *Anemone sylvatica* (?). This plant had done flowering, and we were informed by the Lutheran priest at Oberhalden that the flowers are yellow as well as white.[1] This priest is a very agreeable man, and, like most educated Norwegians, speaks English fairly well. Strange to say, the only stone building in the neighbourhood—the church—had been destroyed by fire, owing to overheating, after a new organ had been put in. When we sympathised with him about this, he said, "It was very sorrowful to see the eldest church in the valley destroyed, but I hope it will soon be reparated." Other finds in this locality were *Betula nana*, *Rubus Chamæmorus* (in flower and fruit), *Andromeda polifolia*, *Nymphæa alba*, *Struthiopteris Germanica*, *Asplenium septentrionale* (at Namsos), *Lysimachia thyrsiflora*, *Calluna vulgaris* (which is abundant in the south of Norway, but not so common in other parts), also *Splachnum luteum*, a curious moss.

After this pleasant digression, we returned to Trondhjem by the way we had come. At Namsos, where we had to wait many hours for the steamer, we were examined by Mr. Sommerschield as to the origin of the word "hammock," which he said was not to be found in "Webster," but his philological researches had enabled him to say that it was of Red-Indian origin. It was interesting on board the steamer to watch the operations of the skua, a bird of prey, which, being unable to catch fish for itself, chases gulls and terns until they disgorge and drop the fish which they have caught. The skua then pounces upon its booty, sometimes catching it before it reaches the sea. Some exciting chases were witnessed.

The weather being wet when we got back to Trondhjem, we spent no more time there than was required to see the famous old Gothic cathedral. Like so many other build-

[1] Possibly there were two species—*Anemone nemorosa*, L., and *A. ranunculoides*, L.

ings in Norway, it has to be recorded of this also, that it has been repeatedly injured by fire, and wholly destroyed in the sixteenth, and again in the eighteenth, century. A thorough restoration to its early form is now going on, the stone used being the bluish soapstone (klæbersten), from quarries near Trondhjem, and marble from the island of Almenningen.

Taking train from Trondhjem for about forty miles to Storen, a pretty place at the confluence of the Sokna and Gula rivers, we hired a carriage on 27th July for a two days' drive to our botanical ground, and we had not proceeded far before we came to a sign-post at a cross-road with the words, "Fra Trondjhem till Kristiania over Dovre." This looked like getting to business at last, and one could not help thinking that if the Norwegian language were all as plain as this, any Scotsman might travel through Norway without any trouble as regards the language. But unfortunately it is not so, and the greatest help a Britisher gets in making himself understood arises from the humiliating fact that English is spoken in all the parts of Norway which are frequented by tourists.

Early in the twelfth century the King of Norway caused roads to be made and inns to be established for the use of travellers crossing the Dovrefjeld. Some of these mountain inns, or posting stations, are still subsidised by the State.

Our drive this day was interesting in many ways, from the varying scenery and the plants met with, or at least seen from the carriage; and as we were often going up hill at a foot's pace it was possible to leave the carriage and gather a specimen from time to time. We got as far as Stuen, where we spent a night very comfortably. A stove in the sitting-room at night was welcome, as it is a cold region; indeed, for the next ten days we rather missed our winter clothing in the evenings. Among the plants observed were—*Saxifraga cotyledon*, *S. aizoides* (with its var. *aurantiaca*), and *S. stellaris*; *Eriophorum alpinum*, a very delicate plant growing in great abundance in marshy uplands, and not likely to be disestablished by drainage, as has been the case in Scotland; *Campanula*

latifolia; *Oxyria reniformis.* It is said that in northern Norway *Oxyria* is cultivated as a substitute for corn, kept in a frozen state in winter, and boiled down to a pulp for use, being frequently mixed with flour and made into Fladbrod, the flat bread resembling thin oat-cake, with which travellers in Norway are familiar.

Next morning we drove on through a beautiful alpine country, abounding in grand scenery. The crossing of a deep ravine by a bridge reminded me of the Via Mala and the Splügen Pass. At Aune, we came upon the river Driva, which we were now to trace upwards to near its source, and after a steady ascent the evening brought us to Kongsvold, which had from the first been fixed upon as our botanical headquarters.

Kongsvold is one of the oldest "stations" on the Dovrefjeld. It stands near the head of Glen Driva, a narrow pass with steep hills on either side, and is about three thousand feet above sea-level. The hotel can accommodate seventy visitors, and it was full the week before our arrival. Many are attracted by the fine air, and invalids or old persons are advised not to return suddenly to the plains after a stay in the mountains, owing to the great difference in temperature. There is a large establishment of buildings belonging to the hotel, but no village, church, or house within a good many miles. Visitors are made very comfortable, and can live *en pension* at the extremely moderate figure of three kroner (3s. 4½d.) a day. The hotel encourages botany, providing not only paper for drying plants, but also a hot room for drying the paper. Botanists from many parts were there, especially from Sweden, and we got valuable help in the naming of plants from some of them. We had to depend a good deal on this, not having a book of Norwegian flora. Special thanks are due to Rektor Axel Arrhenius, of Helsingfors, Finland, who was most obliging in this respect. He was not one of those who spoke English, but we found a common ground in the French tongue in conversing with him.

In the drive up the valley of the Driva so many interesting plants were observed, some known to us, some unknown, that we did not feel inclined at once to take to

the mountains. Indeed, when such things as *Saxifraga cernua*, *Veronica saxatilis*, and *Cystopteris montana* are found growing by the roadside, as they do in this glen, one does not feel very far from the top of Ben Lawers. We accordingly spent the first day or two in the neighbourhood of the inn; and, without any hill climbing, we found, in addition to plants already named—*Primula Scotica* (*farinosa?*), *Salix reticulata* and *S. herbacea*, *Astragalus alpinus* and *A. oroboides*, *Thalictrum alpinum*, *Dryas octopetala*, *Filago montana*, *Erigeron alpinus* and *E. elongatus*, *Silene acaulis*, *Lychnis alpina* (called in Norway *Viscaria alpina*), *Poa alpina* and *P. cæsia*, *Sedum Rhodiola* and *S. annuum*, *Lycopodium selaginoides*, *Konigia Islandica* (a small and rare plant of the order Polygonaceæ, growing in the stream behind the hotel), *Saxifraga cæspitosa* and *S. adscendens* (this last is the name as given to us, but I do not find it in the "Norsk Flora," of Hoffstad), *Gentiana nivalis* and *G. tenella*, *Polemonium cæruleum*, *Ranunculus hyperboreus*, *Anemone pulsatilla*, *Gnaphalium Norvegicum* (a British plant), *Carex capillaris*, *Kobresia caricina* and *K. scirpina*, *Asplenium viride*, *Cystopteris montana*. This, with us, rare fern was growing plentifully in the birch woods near the hotel, not on rocks, where we were looking for it, but in the grass under out feet, and we gathered our first specimens under a heavy fire of mosquitoes.

After this we took to the hill called Knutsho, with its three tops, which stands behind the hotel, and is about five thousand feet above the sea—a climb of only two thousand feet. Unlike the mountains in many other parts of the country, there are neither trees nor rocky precipices to interfere with the vegetation all over the hill, which thus presents no difficulty to the climber, and rewards the botanist at every step. After going through the brushwood at the beginning of the ascent, a fine view is obtained, in the opposite direction, of Snæhätta ("the snow hat"), eight thousand feet, the highest mountain in this district; the ascent of which was made by a party of ladies and gentlemen staying at Kongsvold during our visit. Then some new flowers began to appear—*Viola biflora*, *Pedicularis Œderi* and *P. Lapponica*, *Ranunculus nivalis*, *R. glacialis*, *R. pygmæus*, *Gymnadenia albida*, *Petasites frigida*, *Alsine*

biflora, Campanula uniflora (considered "a good plant" by our Swedish friends), *Cardamine bellidifolia, Saxifraga rivularis* and *S. oppositifolia, Cerastium alpinum, Draba alpina, Phyllodoce cærulea, Azalea procumbens.*

On other visits to the hill there were found—*Andromeda hypnoides, Diapensia Lapponica, Papaver nudicaule* (scarce), *Arabis alpina, Androsace septentrionalis, Arctostaphylos alpinus, Salix phylicifolia, S. Myrsinites, S. Lapponum, S. serpyllifolia, Wahlbergella apetala*, a caryophyllaceous plant, etc.

We were rather late in the season for seeing some of the plants in flower. A fortnight earlier would have been a better time for a full display of *Dryas octopetala* (one plant of which was found, *flore pleno*), *Primula Scotica* (also *P. stricta*, which we did not see at all), and others. But a few which had ceased flowering in the valley were in good flower up the hill, *e.g. Saxifraga oppositifolia* and *S. cæspitosa.* We were told that nothing was to be gained by botanising from any of the other "stations," as no notable plants were to be found there which are not to be got from Kongsvold. If time had permitted, however, we should have liked to test this, as some of the copses, lakes, and marshes which we passed, both in driving up the mountains and afterwards in driving down on the other side, looked very tempting. One could not help remarking the absence from Knutsho of some flowers which would have been looked for on our own high mountains, such as our heathers, *Alchemilla alpina, Thymus Serpyllum.* The ground where these might have been expected was mostly covered with *Betula nana, Azalea procumbens, Arctostaphylos*, etc. *Digitalis purpurea* was not to be seen anywhere. Its place seemed to be taken by another deadly poison, *Aconitum napellus.* A beautiful sight was occasionally met with in the shape of a natural rock-garden far up the hill. The exquisite grouping of rare Alpines, of lovely shades of red, white, blue, and yellow, in such a place was very striking, and could not be surpassed in any botanic garden.

I observed a *Leontodon* on the roadside at Kongsvold, evidently different from our *L. Taraxacum*, but I did not examine it particularly. I now see from the "Norsk

Flora" that *L. autumnalis* and *L. hispidus* are natives of Norway, and it was probably one of these.

There are three species of *Botrychium* in the "Norsk Flora"—*B. lunaria*, *B. rutaceum*, and *B. ternatum*. We may have got them all here.

After a most enjoyable stay of ten days at Kongsvold, we continued our drive over the Dovrefjeld, on Monday, 7th August, passing the old "stations" of Jerkin (the highest point on the route), and Folkstuen, where we joined a large company at an excellent dinner. This place seems to be a favourite. It is in a very airy situation, on a moorland 3120 feet above the sea, commanding a fine view of the Snæhätta range, and said to have good shooting in the neighbourhood. The game in this district includes willow grouse, ptarmigan, and capercailzie.

Passing out of alpine regions at Domaas, where a cross-road leads to the Romsdal Fjord and Molde, we spent the night at Toftemoen, in the valley of the Laagen, near which is the parish church of Dovre. A *Campanula* with very small flowers was observed here, probably the variety of *rotundifolia* called *parviflora* gathered by the Scottish Alpine Botanical Club on their visit to Norway in 1887.

Next morning we had a picturesque though dusty drive down the valley to the railway terminus at Otta, enjoying on the way a feast of *Multibær* (*Rubus Chamæmorus*), which was now ripe. Served with sugar and cream, at the end of table d'hôte, this makes an excellent dish. From Otta the train brought us through the fertile Gudbrandsdal, to Lillehammer, a town at the upper end of Lake Mjösen. Large quantities of *Tamarix* were observed during these last two days, but we were not free to obtain specimens. We were told that it was *T. Germanica*. Lake Mjösen, famous for its salmon-trout, is the largest lake in Norway (sixty-two miles long), having a good many towns and villages on its shores, the largest of which is Hamar, with over five thousand inhabitants. Next day we sailed the whole length of the lake, to Eidsvold, at its southern extremity, reaching Christiania in the evening by train.

Having brought our tour to a close in Christiania, and having a whole day to spend there, it seemed fitting to

pay a visit to the Botanic Garden, which is in the outskirts of the city. It contains an interesting collection of the wild flowers of Norway; but in other respects seemed scarcely worthy of a European capital. Christiania is very hot in the summer months—Norwegians say it is the hottest town in Europe,—and probably the Botanic Garden is dried up by the month of August, and would be seen to more advantage earlier in the season. On the morning of 11th August we sailed in s.s. "Scotland," Captain Stephensen, with whom I had made the same voyage in 1897. The captain was anxious that we should see Norway in winter, as well as in summer, and distributed among the passengers a treatise extolling the winter sports and other attractions of the country; but this is not the place to describe these. Grangemouth was reached on 14th August.

This somewhat sketchy and imperfect narrative of a holiday tour is submitted in the hope that some more learned botanist may be tempted to follow our example by exploring a district of great botanical interest, and may thus be able to furnish the Society with a more exhaustive and authoritative report on the products of the Dovrefjeld than I am able to do.

On Variations in Lycopodium clavatum, Linn., with their bearing on Phylogeny. By R. A. Robertson, M.A., B.Sc. (With three Plates.)

(Read 10th May 1900).

Some years ago, while exploring a wood occupying the northern side of an exposed hill on the Craighall estate in the north-east of Perthshire, I came across a luxuriant patch of *Lycopodium clavatum*. Careful searching showed that all the plants were in the vegetative phase. Having had occasion to be in the district nearly every year since, I visited the Lycopod station, but always failed to obtain any cones. The great storm of November 1893 practically levelled the wood, hardly a tree being left standing. Some years elapsed before the fallen timber was removed and the ground cleared. It has not yet

been replanted, so that what was once shady wood is now an open exposed moorland, with the usual covering —*Erica*, *Vaccinium*, *Trientalis*, *Blechnum*, and so forth. On paying my annual visit to the spot last summer, I was much interested on discovering that the Lycopods were now bearing cones, and bearing them in profusion such as I had never seen before. Further examination revealed the still more interesting feature that a large percentage of the plants showed marked variations, consisting of extra branching of the strobiliferous axes, branching of the cones, and metamorphy of the cones into ordinary leafy shoots.

Taking a rough estimate, I should say that on from 20 to 30 per cent. of the erect axes some of these variations were found. I collected a quantity from one small area taken at random, and from this made a selection of specimens showing variations. Of this selected material, 87 per cent. had extra branching of the strobiliferous axes, 66 per cent. exhibited branching of the cones, and in 9 per cent. the cones were completely, or almost completely, metamorphosed into leafy shoots; two or all three variations might occur on the same axis, and about 60 per cent. exhibited branching of the axis associated with branching of the cones.

These specimens appear interesting if taken as indicating the wide range of variability in plant members; they are important in the consideration of the possible effects of change of environment on the plant economy; and further, they are instructive from the light they throw on the phylogeny of the group.

In the following notes are described some of the most interesting variations, as figured in Plates I. and II.:—

In Fig. 1 the erect axis supports a terminal cone which has produced, as a lateral branch, a well developed cone just above its base. The axis branches twice, first about the middle of its length, and again higher up, about half an inch below the base of the terminal cone. In the former case the branch consists of a long-stalked lateral cone on the right, and in the latter a short-stalked lateral cone on the left, both cones being of average size.

The solitary terminal cone of Fig. 2 has two lateral branch cones both on the same side, the one coming off a little above the other. The axis bears a little above the middle of its length one branch on the right, consisting of a small lateral cone on a long stalk.

Fig. 3 shows a variation on Fig. 2.

The two branches of the terminal cone arise on different sides, and at slightly different levels. The axis bears half-way down a long-stalked cone as a lateral branch.

The axis in Fig. 4 bears three cones, a solitary terminal on a short stalk, and two lateral sessile cones at the same level on opposite sides and just below the base of the terminal.

Fig. 5 is somewhat similar to Fig. 4, except that the lateral cones are both stalked, and originate at different levels right and left of the terminal, the left cone being longer stalked than the right.

In Fig. 6 the axis bears three cones, a terminal and two laterals, all with well-developed stalks, the two laterals right and left and about the same level below the terminal. An interesting point here is that the axis of the terminal cone has continued its growth, and bears a small tuft of sterile sporophylls having the characters of ordinary foliage leaves.

Fig. 7 is instructive when compared with Fig. 2. The terminal cone has two lateral branch cones on the right, the upper nearly half an inch above its base, and the lower just below the upper one. The lower lateral cone arising on the axis in Fig. 2 is represented here by a lateral branch bearing ordinary foliage leaves. This is to be regarded as a completely sterilised cone, the sporangia having aborted, and the sporophylls being transformed into foliage leaves.

Fig. 8 should be compared with Fig. 7. The axis bears at its apex two normal cones. Near its base, in the same position as the sterile cone of Fig. 7, is a long branch bearing an ordinary cone of average size.

The next four examples (Plate II.), along with Fig. 7 (Plate I.), form an instructive series, as they show stages of progressive sterilisation of the whole strobilus.

In Fig. 9, at about the middle of its length, the stro-

biliferous axis bears a long-stalked lateral cone of small size. The upper half of this cone is sterilised, its sporophylls resembling ordinary leaves; of the basal half, the sporophylls on the adaxial side are fertile, those on the abaxial side sterile. In consequence of the greater growth on the adaxial side, due to the developing sporangia, the cone has been curved over towards its abaxial sterile side.

Higher up on the opposite side a second lateral cone, almost sessile, arises very close to the base of the terminal, which gives off a lateral branch cone on the right near its base.

Fig. 10 shows a further stage in the process of sterilisation. The lower lateral cone, again long-stalked and arising about half-way up the axis, is completely sterilised, with the exception of some half-dozen sporophylls on the adaxial side. These fertile sporophylls, however, like the sterile ones, have all the characters of ordinary foliage leaves, so that the process of metamorphosis of sporophylls into foliage leaves in this case would appear to have outstripped the abortion of the sporangia. The other structures on the axis are similar to these on Fig. 9, save that the fertile spikes are better developed, and the left lateral cone originates farther down the axis, and is stalked.

Figs. 11 and 12, like 7 (Plate I.), show the extreme case where the lower lateral cone is completely sterilised and purely vegetative. The sporangia have aborted, and the cones have the appearance of small lateral foliage shoots on short stalks.

In Fig. 11 another noteworthy feature can be observed: the part of the axis below the insertion of the sterile cone shows a gradual passage by increase in size from the characteristic appressed scales of the normal strobiliferous axis into foliage leaves. The terminal cone bears a lateral branch cone on the left, a quarter of an inch above its base; while a second lateral cone of small size arises directly from the axis on the right, just at the base of the apical.

A curious trident appearance is produced in Fig. 12 by the branching of the terminal cone. It gives off a

branch on either side about a quarter of an inch above its base, and both about the same level.

In Fig. 13 the axis branches in its lower third giving off a long-stalked lateral cone on the left, which in turn bears a small lateral branch cone on the left about its middle. The terminal cone here also branches, bearing a lateral on the right, while another lateral arises on the left of the axis, and sessile with the base of the terminal.

Fig. 14 shows an axis bearing a solitary terminal cone of large size and somewhat thicker than normal.

Fig. 15 presents a striking appearance. The terminal cone has branched, and two lateral cones arise on the axis at the same level, each stalked.

Fig. 16 is an example of a solitary terminal cone like Fig. 14, which, however, has branched, bearing a lateral cone near its middle on the left.

We consider next the size variations exhibited by these specimens.

If the average size of a normal cone be taken as 40 to 45 mm., we find the terminal cones in these specimens varying from this to as much as a quarter more. When the terminal cone branched near its base, the difference in size between the branch and the part of the terminal above the origin of the branch was very small. This is well seen in Fig. 17 (Plate III.), which represents a longitudinal section of a very young branched cone. The higher the point of origin of the branch cone, the greater this difference in size became. When the branch arose one-third or half-way up from the base of the main cone, the lateral character of the branch was very apparent, the free part of the main cone being markedly larger, and forming the continuation of the axis. From measurements, it was found that the length ratio between the branch cone and the free part of the main cone was as 9 to 11.

The lateral cones produced in the middle of the length of the strobiliferous axis, or lower, varied from normal to half-size, the average being somewhat between; the length ratio of lateral to normal cone being as 5 to 8.

Complete sterilisation was found only in the lower lateral cones. It was accompanied by branching of the terminal cone, and was further associated with reduction

in the size of the other cones on the axis; but there were exceptions to this last, in that the apical cone might be longer than the average. Further, sterilisation was usually associated with reduction in size of the cone. Taking the average length of a normal fertile cone at the figure stated, we find the length ratio of sterilised to normal cone as 3 to 8.

Sporophyll variations were studied in dissections of branched and sterilised cones. The normal sporophyll may be described as ovate in outline, contracted basally, and continued at the apex into a long hair-like prolongation. Its margins are irregularly serrate. Its length is about 5, and its breadth about 2 mm. The ordinary foliage leaf, again, is narrow elongate-lanceolate, simple, sessile, with its apex also prolonged into an awn-like structure. Its margin is not appreciably serrate. Its length is about 7 to 8, and its breadth $\frac{3}{4}$ mm.

No variation of the nature of lobing or branching of the sporophyll was met with, but forms intermediate between sporophyll and foliage leaf occurred. These were to be seen occasionally in the middle of such a semi-sterilised cone as that of Fig. 9 (Plate II.). These intermediate sporophylls were about 1 mm. in breadth, and about $6\frac{1}{2}$ mm. in length; the outline was similar to that of the foliage leaf, but the apical prolongation was shorter, and resembled that of the normal sporophyll, and further, there was a slight indication of marginal serration. Such intermediate leaves had sporangia, so that the metamorphosis of cone into foliage shoot would appear to be first manifested in the change of the sporophyll.

For the study of the branching serial sections, radial, tangential, and transverse of young and old, branched, and partially and completely sterilised cones were prepared. I hoped to discover some variation in histological structure, but as yet I have nothing to record on this head.

These preparations were also carefully searched for variations in the sporangia, for a possible branching—the occurrence of which would be both interesting and important. On dissecting similar strobili, I found among the normal sporangia of a reniform or horse-shoe shape others whose shape varied. Some were bulkier than usual,

and of irregular and unsymmetrical outline; others, again, had a shape evidently a modification of the typical reniform. In these last, along the adaxial side ran a deep vertical groove, while the two ends of the horse shoe were, as it were, pushed together so that an appearance was produced of two small oval sporangia subtended by a single leaf. This, which looked like a branching, was merely a lobing, the cavities of the two lobes being continuous on the abaxial side, and the two arising on one stalk. From such a lobed condition to a complete branching would be but a step, and in some of my preparations there appears evidence that this step has been taken and that branching does occur (Fig. 18, Plate III., a photo-micrograph of a longitudinal tangential section of a semi-sterilised cone). Such an appearance as in this figure would be produced, however, by a deeply lobed sporangium, if cut in a particular plane, and I prefer to regard this as a case of a very deeply lobed sporangium.

From the above, it will be apparent that the capability of variation in the strobilus and associated organs of *Lycopodium clavatum* is not inconsiderable. Thus, meristic variations occur as branchings of the strobiliferous axes and cones, in the size of the cones, in the size, shape, and lobing of the sporangia, and in the point of origin of the branches; while homœotic variations appear in the metamorphoses of cones into foliage shoots, complete or partial,—in fact, all stages occur.

The scheme of correlation of these various features works out as follows:—

Branching of the Strobilus is accompanied by (*a*) diminution in size of the main strobilus, as well as of its branch or branches; (*b*) variations in the sporangia, such as changes in shape and size, some being bulkier than normal and of irregular shape, especially near the point of origin of branches, others showing incipient branching.

Sterilisation of the Strobilus is associated with (*a*) very marked diminution in size—the sterile strobilus being about half, or less than half, the normal length; (*b*) metamorphy of the sporophylls into foliage leaves—this may occur before the sporangia disappear; (*c*) variations in the sporangia, such as occur in the branched strobilus.

PLATE I.

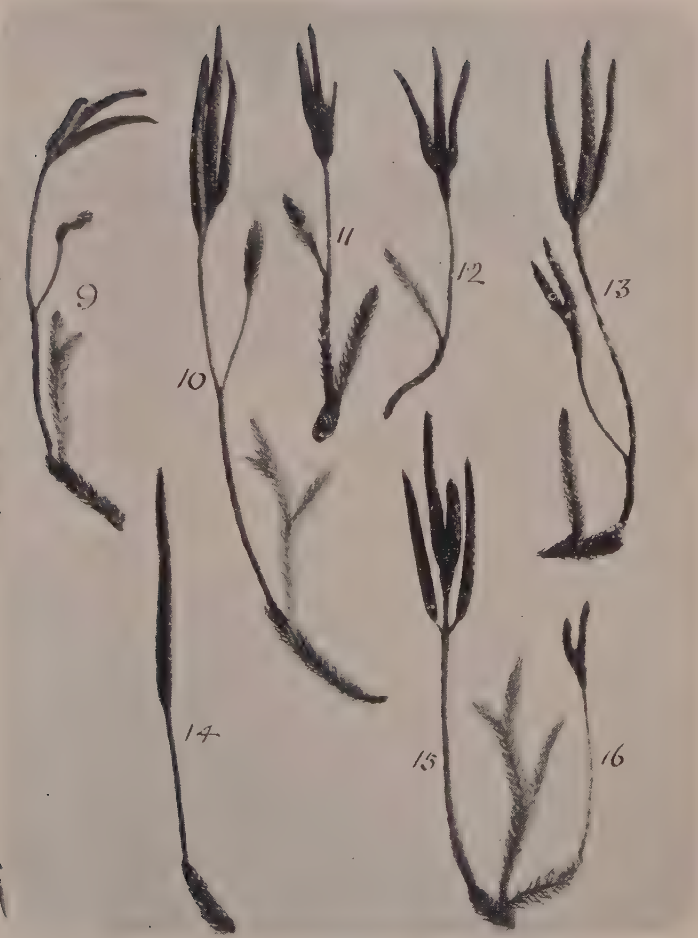


PLATE II.

FIG. 17.—PLATE III.

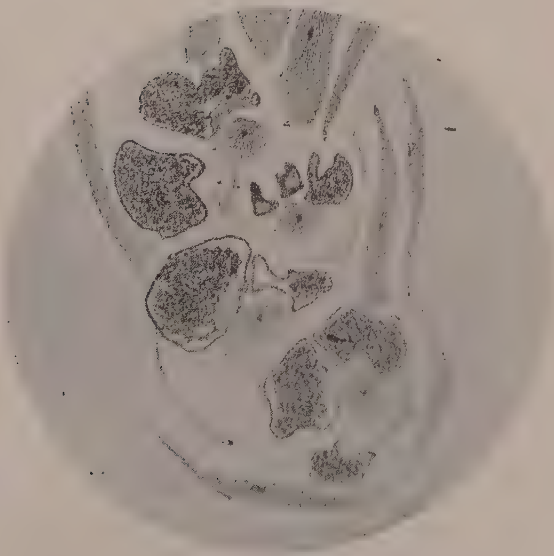


FIG. 18.—PLATE III.

In answer to the query of what has caused these variations, it may be submitted that the change in the environment has acted as a variation-stimulus. The inherent tendency to variation may have been emphasised, and the morphological results brought into marked prominence by the cumulative influence of all the external stimuli called into play by the sudden change in the environment—the change from a life in the shade to a life in the open, involving the free access of light and air, as well as changed conditions of competition. In addition, it is possible that a factor of some importance, no doubt dependent on the former so far, is supplied by the long inhibition of the reproductive functions and the concurrent long duration of the purely vegetative activity.

Whatever difference of opinion there may be as to the cause of these variations, it may be admitted that they are not without some interest when considered from the point of view of descent, as bearing on the possible mode of evolution of the *Lycopodinæ* from lower forms.

"The study of variations," says Bateson ("Materials," pp. 17 and 30), "offers a means whereby we may hope to see the processes of evolution. In variation we look to see evolution rolling out before our eyes." Again, "the facts of variation must be the test of phylogenetic possibility. . . . If, therefore, we can see the variations, we shall see the precise mode by which the descent is effected."

Viewed in this light, if these variations have any meaning, it would appear to be that branching of the strobilus and sterilisation of sporogenous tissues have played a part in the evolution of the Lycopods. These are two of the factors which Bower formulates in his "Hypothesis of the Strobilus" ("Annals of Botany," vol. viii.) to explain the mode of evolution of the sporophyte of the *Vascular Cryptogams* from the simple sporogonial head of the *Bryophyta*. Other two factors which have played a part are, according to Bower, eruption of sporangiophores from a previously smooth surface, and relegation of sporogenous tissue to a superficial position. He shows how, by agency of these, the primitive strobilus of *Phylloglossum*

may have arisen from a simple sporogonial head; and how from such a simple strobilus, by sterilisation and branching of the strobilus, the sporophyte of the higher Lycopods may have been developed. "In the various species of *Lycopodium*," he says ("Proc. Roy. Soc.," 1891–92, p. 270), "the whole plant (exclusive of the protocorm) represents an extended and branched form of such a strobilus of which many of the sporophylls have been sterilised and appear as the foliage leaves, having no sporangia." Among other evidence from *Lycopodium clavatum*, he cites the fact that "arrested sporangia are frequently present, and may be found either at the base or the apex of the strobilus" ("Phil. Trans. Roy. Soc.," vol. 185, p. 521).

The variations described above go farther than this, and their interest is therefore enhanced as being extreme cases confirmatory of this particular point in Bower's theory. Not only do they show arrest of sporangia, but they also demonstrate all the stages from partial to complete sterilisation of the strobilus, with the passage from sporogenous to vegetative tissue, as well as branching of the strobilus and incipient branching of the sporangia.

MEHNERT'S (1) PRINCIPLE OF "TIME DISPLACEMENTS" (2) APPLIED TO THE DEVELOPMENT OF THE SPOROPHYTE. By R. A. ROBERTSON, M.A., B.Sc.

(Read 10th May 1900.)

It is admitted by biologists that Van Baer's principle of biogenesis—the life history of the individual is a short repetition of that of the race—does not hold good for every type.

Among highly specialised forms which are closely related there may be very marked differences in the development. New stages may be intercalated, others may be passed through very rapidly, and others omitted altogether. Organs which are more recent may appear earlier in the ontogeny than others which are phylogenetically older. The development of the individual may be

the converse of what is believed to be the development of the race.

To explain these cases of inversion of the order of sequence, where there is a want of correspondence between ontogeny and phylogeny, Mehnert formulates his principle of "time displacements." He would correlate these inversions with changes in the structural complexity and functional importance of organs.

He submits that the rate of development of an organ is accelerated in proportion as its structural complexity and its functional importance increase, while with diminution in physiological importance and structural differentiation, the rate of development is in the same degree retarded. Mehnert adduces numerous examples and measurements from the animal kingdom in illustration of his principle.

[A lucid account of Mehnert's theory, and a discussion of it in so far as it is of interest to the biologist, will be found in the "Proc. of the Scots. Micr. Soc." for 1898–99, by Prof. J. Arthur Thomson. To this paper I am indebted for an introduction to Mehnert's principles, and from it I take the term "time displacements."]

My object is to point out the interest of this principle from the botanist's point of view, and to cite illustrations in support of it, in the development of the sporophyte. In addition, its bearing on the development of the gametophyte of the higher plants will be indicated, and other cognate matters of interest alluded to.

Botanists now generally admit the existence of an alternation of generations, at least in the higher plants: the life cycle consists of a sexual and an asexual phase, which follow each other in regular succession. This alternation is seen to greatest advantage in the *Vascular Cryptogams*; is obvious in the mosses; is present, though not so conspicuously, in the flowering plants; and is only just indicated in the *Thallophytes.*

While the fact of the existence of such an alternation is accepted, phylogenetic relationship between the two generations is disputed. Various theories of the sporophyte have been advanced, among others recently by Lang (5) and Klebs (9). Perhaps the two most discussed, however, are those of Pringsheim (3) and Bower. In that of the former, the two generations are looked upon

as homologous—the sporophyte being merely a differentiated gametophyte. This theory receives some support from the facts of apospory, the resemblance between the young gametophyte and sporophyte, as noted by Treub (4) in some Lycopods; the existence of sporangia on fern prothalli alongside the sexual organs, described by Lang (5); and analogies with lower algæ having sexual and asexual stages. In regard to the latter, the gametophyte and sporophyte are taken as standing in much the same relation to each other as the sexual and neutral generations of an *Œdogonium*, for example.

Bower (6), on the other hand, contends that the generations are antithetic, and that no homology can be instituted between them, the phylogenetic history of the sporophyte being a history apart, for the gametophyte was in existence before there was the slightest trace of the sporophyte. The latter is a new generation interpolated between successive gametophytes, and has been developed to meet the change in environment from an aquatic to a subaërial life. Bower's theory is supported by evidence derived from a magnificent series of researches on sporangia and sporangiferous organs, as well as from facts observed in a comparative survey of all types of sporophyte, from the lowest to the highest forms.

In the development of the sporophyte with the phylogenetic history ascribed to it in this latter theory, Mehnert's principles find their best illustration.

The first function of the primitive sporophyte was spore bearing, and the simplest sporophyte among recent forms is represented by a mass of sporogenous cells. Later, change in environment from an aquatic to a subaerial life rendered necessary the development of a vegetative system.

This was obtained by sterilisation of potential sporogenous cells, and further specialisation (Bower, 7), and a series of types among the *Hepaticæ* and *Musci* can be adduced showing progressively increasing structural complexity and physiological importance in the vegetative system.

In his theory of the strobilus, Bower (8) traces the mode in which the independent sporophyte of the higher

plants may have developed from a simple strobilus which was evolved by a process of variation from the simple sporogonial head of the *Bryophyta*.

On this theory, sporogenous organs must be held as phylogenetically older than vegetative, and according to Van Baer's law ought to appear first in the developmental history of the individual. Instead of this, the ontogeny reverses the phylogeny, and the vegetative organs are the first to appear, the sporogenous subsequently developing, but not uncommonly after long delay which may amount to years.

In dealing with this difficulty of incongruence between individual and racial history, Bower ("Phil. Trans." *loc. cit.*) states that "the development of the individual sporophyte cannot be taken *en bloc* as illustrating the history of the sporophyte at large," and that the extensive vegetative phase preceding spore production in the individual was of recent origin, appearing as an intercalation in the life history, and that spore production at first, as evidenced by the lower forms, was the sole function of the sporophyte. He gives premier place to the phylogenetic conclusions based on a comparative study of the lower forms, and would have them used as guides and checks in the interpretation of the individual development.

Following this advice, and returning to the lower forms, let us see what illustrations are afforded in them of Mehnert's principle, before we apply it to this case of inversion of the order of sequence in the development of the higher sporophytes. Looking for a purely sporogenous type of sporophyte, we find it exemplified in such green algæ as *Œdogonium* and *Coleochæte*. In the former it is very rudimentary — the protoplast of the zygote segmenting into a few naked cells, which ultimately escape as zoospores; in *Coleochæte*, the cells formed by segmentation of the zygote are enclosed in membranes, but each cell ultimately emits its protoplast as a free-swimming spore. Passing to the *Hepaticæ*, we find an advance on this simple type of sporophyte: a distinction can now be drawn between sporogenous and vegetative tissues—the differentiation being rendered necessary by the change in environment from aquatic to subaërial

conditions of life. Part of the sporogenous tissue has been sterilised to act as an envelope to the rest. In such a type as this, *e.g. Riccia*, the envelope may be taken as the first rudiments of a vegetative system. The advance on the *Coleochæte* type is, however, very slight, and the development of the sporogenous and the vegetative tissues are practically contemporaneous. With the rise of the sporophyte, the vegetative system becomes better differentiated, and of progressively greater physiological importance, and according to Mehnert's principle its development is accelerated. Thus, in such forms as *Marchantia*, *Pellia*, and so forth, an important vegetative organ—the foot—appears, and develops somewhat before the sporogenous tissue; a "time displacement" in the form of an acceleration of development has occurred, concurrent with the increase in importance and the greater differentiation.

Vegetative differentiation and physiological importance of the vegetative system are more marked in *Anthoceros*, and there is a corresponding acceleration in the development of the vegetative system. The vegetative system comprises the foot, the columella, and the envelope of the sporogonium, which is chlorophyllous and has stomata, the meristem, etc. Of these, the columella and the foot are developed before the sporogenous organs. While the greater part of the vegetative system has outstripped the sporogenous system in its rate of development, part is contemporaneous with it.

In the *Musci*, with the vegetative system differentiated into absorbent and conducting parts—foot and seta, and assimilating organ—apophysis with chlorophyll and stomata, conspicuous in the *Splachnums* (Vaizey, 10), the same acceleration in the rate of development is seen as in the higher *Hepaticæ*,—the sporogenous tissue on the whole developing late (Campbell, 16).

Arrived at the highest type of *Bryophyta*, we are confronted by a wide gap. It is a long cry from even the most developed sporogonium of a *Bryophyte* to the sporophyte of the simplest *Vascular Cryptogam*. Our appreciation of the width of the gap is emphasised on remembering that while on the one side, as sporophyte,

we meet with a parasitic structure of transitory character —a fruit—an organ in a kind of fashion of the gametophyte, on the other side "the organ" is represented by an independent organism of considerable permanence, and from being the secondary has now become the primary member in the life cycle.

By whatever stages the sporophyte has advanced from parasitism to independence, the progress has resulted in a very marked increase in the structural complexity and physiological importance of the vegetative organs of the sporophyte.

The physiological importance of its vegetative organs is further emphasised by those cases where, owing to internal or external causes, spore production is long deferred, or inhibited, and the plant is dependent for reproduction on the vegetative multiplication of the sporophyte.

The slight acceleration in the rate of development of vegetative over sporogenous organs indicated in the *Bryophytes* becomes exaggerated in the *Vascular Cryptogams* and higher forms, as might be expected from the very marked increase in complexity of structure and functional importance, into a great "time displacement," inasmuch as the vegetative system may be developed for many years before there is any trace of the appearance of the sporogenous organs.

Traced upwards to the higher flowering plants, the importance of the sporophyte as a whole, and of its vegetative organs in particular, is found to increase, so that ultimately the relative positions of the generations are reversed. The pendulum has swung to the other side, and while at the lower end of the series the sporophyte was parasitic on the gametophyte, and consisted merely of a mass of sporogenous with no vegetative tissue, at the upper end the gametophyte is parasitic on the sporophyte, and its vegetative tissue is reduced almost to the vanishing-point.

Thus, in contrast to the marked acceleration in the rate of development of the vegetative organs of the sporophyte in correlation with their increased functional and structural importance, we find in the gametophyte a "time displacement" due to retardation of the development

of the vegetative system following on its loss of structural differentiation and functional insignificance. This "time displacement" is best seen in the specialised heterosporous forms.

For example, in *Selaginella* the male prothallus and antheridium are contemporaneously developed almost, so much has the rate of development of the prothallus been retarded in consequence of functional and structural insignificance. Similarly, in the female the sub-diaphragmatic part of the prothallus shows such retardation in its development that it only appears after formation of the sexual organs. Similar "time displacements" appear in the angiosperms. The female prothallus—the antipodals,—insignificant both in structure and function, has had its development so slowed down that it appears contemporaneously with the egg apparatus, and if the endosperm be of a prothallial nature, then the "time displacement" is still more marked.

Beginning with the lowest plant forms, we find asexuality prevailing; as the upward progress is followed, sexuality is gradually introduced and gametophytes appear; next, an introduction of the asexual phase recurs, and sporophytes result and alternation. At the upper end of the line, the sexual phase seems to be disappearing as the sexual plant becomes a vanishing quantity. The prevailing trend in the evolution of the higher plants would seem to be towards the production of a series of asexual plants, *i.e.* a return to the primitive condition, but with a difference. While in the lowest types asexuality exists with a generalised and simple type of plant body and conduces to permanence, in the highest forms so evolved and specialised—over-specialised, indeed, so far as their system of multiplication is concerned—asexuality, co-existing with a highly specialised vegetative system, would lead to extinction, after the phylogenetic cycle suggested above was complete.

The results of cultivation, which may in a way be looked upon as an artificial process of evolution, bear on this point. The tendency to sterility in highly cultivated plants is known. Cultivated forms tend to hark back to the original type, being in a kind of unstable equi-

librium. In the processes of cultivation, owing to the way in which the pace is forced, time is not permitted for each stage in the evolution to be firmly stamped and individualised in the plant registry—the chromosomes. The consequences to the race as a whole are therefore obscured; but, given that, as in nature, each stage had relatively considerable permanence, over-specialisation would result, leading to senility and, finally, extinction.

One can conceive of the stream of life as a continuous current of low organisms, little changing, eternal; out of the common run, forms are lifted by variation to a higher plane, and from this point of vantage, by further variation, to successively higher and higher levels. Specialisation goes on, while some die out early from unsuitable variations, others continue till over-specialisation accomplishes their extinction.

The main stream flows on relatively unchanged, and more forms are being picked out by variation, and all working along similar—perhaps because mechanical—lines produce a series of forms which, from their structural resemblances, may appear as series in a continuous chain.

Take, for example, the arborescent and herbaceous *Equisetinæ* of the Carboniferous. Similar initial variations may have started them on the upward course—the one, over-specialised, became extinct comparatively early; the other, less specialised, persists to the present.

The gigantic forms had probably attained heterospory, and a corresponding or further stage of evolution to our highest flowering plants,—a stage in which something of the nature of a seed, as in these last, was formed may have been attained to, and then beyond that the stage of asexuality preceding extinction. The disappearance of highly specialised types of plant life in geological times is remarked, and this factor of over-specialisation may have played a part in that disappearance.

In conclusion, a reference may be made to nuclear reduction, *i.e.* the reduction of the number of chromosomes, in so far as it illustrates Mehnert's principle.

Strasburger's (11) view, amended by Hartog (12), is that it occurs in the first protistoid division after fertilisation, and that "it is the necessary secondary result of

fertilisation which would otherwise lead to the indefinite increase of the number of chromosomes by constant doubling." Hertwig (13) states that it may occur before or after fertilisation, citing in example of the former the condition in animal oogenesis, and of the latter, the reducing division described by Klebahn for the germinating zygotes of Desmids.

In *Fucus* (a type described as without alternation of generation), Farmer and Williams (14) describe the reduction as occurring in the oogonium during the ripening of the oospheres: on conjugation, the full number is restored and is found in the vegetative plant—the gametophyte. These observers point out how closely this approximates to the type of animal oogenesis.

On the analogy of certain animal types, as outlined by Beard and Murray (15), the existence in *Fucus* might be suspected of a degenerate sporophyte as the product of germination of the oospore on which the gametophyte would arise aposporously, while the reduction is postponed to the latest minute.

This in turn suggests the possibility of aposporously produced fern prothalli having the full number of chromosomes like the sporophyte, and the necessary nuclear reduction occurring during the maturation of the ovum.

On the other hand, seeing that the reduction occurs in higher forms—certain *Liverworts*, *Gymnosperms*, and *Angiosperms* (see Strasburger, *loc. cit.* for references)—in the spore mother-cells, so that the gametophyte has the half and the sporophyte the full number, and that its appearance is apparently coincident with the development of the sporogenous tissue, the change of position in the life cycle may be of the nature of a "time-displacement."

On this point it would be interesting to have information as to where the nuclear reduction occurs in such forms as *Riccia* and *Coleochæte*, which exhibit the most primitive type of sporophyte; whether, for example, the spores of *Coleochæte* have the half number, and consequently the gametophyte also; or if the reduction occurs at the same point as in *Fucus*, and the gametophyte has the full number; similarly in regard to *Riccia*, whether the sporogonial envelope, as

the first rudiments of the vegetative tissue of a sporophyte, has the full number, and the reduction occurs in the spore mother-cells as in those higher *Hepaticæ* investigated.

Such information would further be of some value in working out the theories of the rise of the sporophyte.

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Artemisia stelleriana, Boss., in Scotland. By G. Claridge Druce, M.A., F.L.S. Communicated by Dr. R. Stewart MacDougall, M.A.

(Read 12th April 1900.)

Artemisia stelleriana, Besser Abrotan. No. 66, t. 5, 1835. "Herba perennis, albido-incana, caulibus validis erectis, foliis oblongis profundo pinnatifidis segmentis plerisque simplicibus obtusus vel subobtusis Capitulis in paniculam anguste thyrsoideam ramis inferioribus distantibus racemosis dispositis, pedicellis brevibus vel subnullis, involvocris globoso-campanulatis dense incanis, squamis lanceolatis floribus subæquantibus" (DC. Prod. VI., 119).—"Refugium Botanicum," W. Wilson Saunders, April 1870, t. 203.

The description in the "Refugium" is from the pen of Mr. J. G. Baker.

The first announcement with which I am acquainted of this plant occurring in the British Isles appeared in the "Journal of Botany," p. 22, 1894, from the pen of Mr. N. Colgan. It was gathered in September 1893 by Mr. C. B. Moffat, in scattered patches for a distance of about three hundred yards on the North Bull, a sandbank which runs along the northern shore of Dublin Bay for some two miles, and is separated from the mainland of county Dublin by a muddy creek a quarter of a mile in width. Here the plant grows vigorously among low sandhills and in association with *Psamma arenaria*, at a point remote from any house or garden.

On pages 104–106 of the same Journal, Mr. Colgan made a further contribution to the subject by giving some information which he had received from a nurseryman of Newry, who said that he had had it in cultivation about fifteen years as an ornamental white foliaged bedding plant, and it was widely distributed for that purpose; and the writer goes on to suggest how from its being often used to make up breast bouquets, which may have been thrown away by some visitor to the North Bull, and have got covered with sand, its occurrence there would be thus accounted for. Mr. Smith, the gardener of Lord Ardilaun's at Saint Anne's Clontarf, which is distant only about a mile in a straight line from the sandhills station, says they had the plant, which they called Siberian Wormwood, in cultivation, he thought, for twenty years, and he used it extensively for carpet-bedding, as it was very easy to train in all shapes, and kept dwarf. He added that rubbish from the garden was carted to the foreshore, this foreshore being the inner shore of "the muddy creek, a quarter of a mile in width, which separates the North Bull from the mainland." Mr. Colgan suggests: "A few scraps of the *Artemisia*, probably fragments of creeping rootstock, are shot out with other garden rubbish at low tide; the rising water floats them off, and a westerly breeze, driving them across the narrow channel, leaves them stranded on the low shores of the North Bull as the tide ebbs. Then the fragments, with vital powers nowise impaired by a few hours' immersion, are swept by the winds across the smooth, low, sandy tracts, until finally arrested by the fringe of *Psamma* along

the outer or sea edge of the bank, they are rapidly buried there under drifting sand. A rainshower or two, a few days of genial warmth, and the aggressive vitality of the plant do the rest; and the stranger from the remote Kamtschatka Peninsula has fairly established a colony on the shores of Ireland." It appears that Miss A. G. Kinahan first found the plant in 1891, and she took cuttings into her garden from a place about three hundred yards from the spot where Mr. C. B. Moffat found it.

Between the publication of these two notes by Mr. Colgan, in the same Journal, on pages 70–75, Professor F. W. Areschoug published a paper on "The Occurrence of *Artemisia stelleriana* in Europe." Previously to this, Professor Areschoug had contributed to the "Botaniska Notiserv," Lund, 1880, p. 137, and 1893, p. 111, an account of the discovery of this plant in the Scandinavian Peninsula. In these papers he endeavoured to show the probability of its being indigenous to Europe, and of its representing a flora now becoming extinct in our part of the globe. He mentions that the plant was met with on the west coast of Skane, the most southerly province of Sweden, in 1876, but did not attract any special attention till 1880, when he visited the place where it grew. It occurred for a distance of about ten miles along the shore, between the two coast towns of Landskrona and Helsingbord, and in groups containing a few plants, and situated several hundred or thousand feet from one another. It extended along a zone immediately above that bearing the (maratime littoral) saline flora, growing on sand and in association with *Elymus arenarius* and *Psamma arenaria.* The wide dispersion of this species along the coast of Skane, as well as the great age which some individuals, judging by the very considerable size, must be assumed to have attained, renders it highly probable that if this plant be a naturalised form in Skane, the naturalisation must have taken place at a time far removed from the present. Professor Areschoug goes on to say that since he noticed it in 1880, the plant has not spread itself along this line of coast, and he deduces from this that if in some mysterious manner the plant was originally introduced into Skane, this must have been at some remote time. He points out that when it was first

observed in 1876, it was not cultivated in the open in Sweden, but it was grown in the Botanical Garden at Copenhagen about 1865, though it soon died out. Professor Areschoug deals at length with the objections which arise as to the plant having been introduced from any part of Europe, either by the agency of man, animals, or water; and points out that the plant grows above the zone of drift-weed that is in the sand zone with *Psamma*, *Elymus*, etc. In Denmark (the north of Zealand), Dr. Gunner Anderson found it in the summer of 1892 ("Botaniska Notiser," 1892, p. 197) in a locality quite similar to the Scanian station, and in association with *Psamma*. In North America, on the eastern free-board of the United States, it occurs in similar circumstances, and the significance of this is still further increased by the fact that *A. stelleriana* lives in Kamtschatka among quite similar environments. The Professor considers that it would have been almost impossible for this plant to have passed over all the interjacent tracts, and found a direct path to localities exactly resembling those which it affects in its first home, if it had originated from gardens in Europe and North America. Against its being native in the European and American localities, is the fact that it has for so long a time escaped attention; but the Professor points out that it may be at a distance easily mistaken for *A. maritima* or *A. absinthium*. And, again, it is a very late flowering species, being in full flower on 22nd September, in Scania; and he also points out that the rather uninteresting zone of vegetation in which it grows may also have led to the plant remaining unnoticed. As the Professor remarks, the plant is a variable one, the plant from Kamtschatka differing from the Scanian plant, as do both from the figure in the "Refugium Botanicum," which is evidently from a cultivated specimen. The Professor shows that an almost equally eccentric geographical range to *A. stelleriana* is to be found in another species of the genus, namely, *A. laciniata*, Willd., which occurs in several parts of the island of Oland and in a few localities in Central Germany, whence there is a gap in its range right to the Altai Mountains, from which locality it is distributed all the way to Amur. In fact, he is of opinion that *A. stelleriana*

belongs to that element of European vegetation, which, in "Acta Universitatis Lundensis," 1886, he termed the Altai flora, and which is almost identical with the Steppes flora of more recent writers. This flora has a circumpolar range without being arctic, and its representatives are now in Europe restricted to widely isolated localities. The Professor believes that after the Glacial period this flora of Central Asia immigrated into Europe in the track of the Arctic flora, and that it was afterwards supplanted more and more in Europe by more southern elements belonging to the Caucasian, Mediterranean, and Atlantic flora. One of the most typical representatives of the Altai flora is *Potentilla fruticosa*, whose area extends from Canada and Newfoundland, right across the northern tracts of North America to the Behring Islands, Kamtschatka, the whole of Siberia to Western Russia, Oland, the north of England and Ireland, and the Pyrenees. Roughly speaking, *A. stelleriana* occupies the same area, though its range is much more interrupted. Professor Areschoug instances the remarkable circumstance that *A. maritima*, which belongs to the Atlantic flora, and which is not rare on other parts of the west coast of Skane, seems to be entirely wanting on that part of the coast where *A. stelleriana* grows. If this be so in the other European stations, it might be possible that *A. maritima*, a later immigrant, has gradually supplanted *A. stelleriana* in the localities more congenial to the former.

In the July of 1895, while walking along the sandy margin of Marazion Bay, near Penzance, during a dense sea mist, I hurriedly gathered a specimen of what I at first thought was a maritime form of *A. absinthium*, but which, on my return to Oxford, I saw was not that species, but which Mr. Arthur Bennett agreed with me in believing to be *A. stelleriana*; and this, on comparison with a Kamtschatka specimen, proved to be correct. In Cornwall it grew with *Eryngium* in the *Psamma* zone, but unfortunately its occurrence on this piece of seacoast can have but little weight in supporting its claims to be considered a native species, since so many plants which we know are not native are found along this particular portion of coast, although its occurrence in a wild (and by this I do

not mean indigenous) condition in Britain was thus put on record for the first time.

Now I am able to report its occurrence in Scotland. In the company of my friends Mr. John Knox, of Forfar, and the Rev. H. J. Riddelsdell, we visited the Forfarshire coast at Lunan Bay in order to search for the Oyster plant (*Pneumaria maritima*), but the magnificent growth of *Elymus arenarius* and *Psamma arundinacea* attracted attention; and in examining these I came across a single plant of what again I hurriedly took to be *A. absinthium*, but which is a small and immature specimen of *A. stelleriana*, with the flowers scarcely open in early August. That it is superficially like *A. absinthium* is therefore proved, especially as but a few days before I had been staying at Slapton, in Devonshire, where there is an immense growth of the English Wormwood. We examined the coast for quite a mile, but saw no other specimen. This grew far away from the saline zone with its *Atriplices* and drifts of seaweed, among the loose sand-dunes with *Elymus*, *Thalictrum dunense*, and *Psamma*. There are a few cottages near, but I could see no *Artemisia* in the gardens of any of them. I am fully cognisant that we cannot draw any positive conclusions from the occurrence of a single specimen, but it must be taken in connection with its occurrence in Scania, hence my long citation from Professor Areschoug's papers. The latitude of the Scanian localities is about 56°, and that of the Forfarshire one about 56°·7, and the situations are almost precisely identical.

Mr. John Knox has kindly made another expedition to Lunan Bay and investigated the northern portion, but has been unable to discover any more specimens.

Professor I. Bayley Balfour kindly writes me that they grow it in great quantity at the Edinburgh Botanic Garden, but neither he nor any of his subordinates are cognisant of its being included in Scottish nurserymen's catalogues.

Mr. John Knox tells me it is cultivated at Glamis Castle, but as Glamis Castle is six miles from the source of the river Lunan, we may dismiss any theory of its being carried by water.

My own belief is that it was introduced to Lunan, and probably from Scania, by birds, but whether through a

Plate I.

Plate II.

fragment being carried in the claws, or by seed passing through the intestinal canal, I do not venture to suggest. My object in compiling this note is merely to draw the attention of Scottish botanists to look closely at any *Artemisia*, especially on the eastern coasts, as the discovery of *Stelleriana* in other places would be of considerable interest.

PRELIMINARY NOTE ON SOME WITCHES' BROOMS. By R. A. ROBERTSON, M.A., B.Sc. (With two Plates.)

(Read 14th June 1900.)

In the following note, the occurrence of four uncommon brooms is recorded, and their more prominent characters are indicated. Researches on tissue minutiæ, and on the predisposing causes, are not completed, but will be supplied in a subsequent paper.

In the course of last summer, my attention was directed to two brooms on coniferous trees—one on a larch, and another on a *Picea nobilis*,—by Mr. K. Hendry, land-steward on Craighall, Perthshire.[1]

While brooms on some coniferous trees are well-known objects—especially that on the silver fir caused by *Æcidium elatinum*,—the occurrence of such malformations on others is comparatively rare.

Tubeuf ("Diseases of Trees," Eng. Trans.) records them for *Abies nordmanniana*, *A. Cephalonica*, *A. Pinsapo*, as well as *A. balsamea*, and *A. pichta*.

Borthwick ("Trans. Bot. Soc.," vol. xxi. p. 196) describes an interesting type of broom, induced by fungus influence on the ordinary Scots fir.

I have not discovered any reference to a broom on *Picea nobilis*, and the only indication I can find of such a structure on the larch is in a short statement in Kerner's "Natural History of Plants" (vol. iv. p. 527) to the effect that brooms on the larch do occur, but that hitherto

[1] To the proprietor of the estate, Lieut.-Gen. Sir James Clerk-Rattray, K.C.B., I am much indebted for kindly granting me permission to utilise the specimens for scientific purposes.

it has not been definitely ascertained what parasitic fungus is the cause of them.

The Craighall broom-bearing larch is one of a small collection of trees forming an open straggling plantation on the south slope of a sheltered glen. The ground drainage is good, and the plant covering consists of *Calluna*, grasses, and other moorland plants, with an occasional patch of rushes. A large number of the trees showed canker spots due to *Peziza Wilkommii*, and also leaves geniculate from the attacks of *Chermes laricis*. The tree bearing the broom was no exception, the broom in particular showing an abundance of *Peziza* disks and *Chermes*-attacked needles. One half of the broom—that half worst infected with *Peziza*—was dead, the other half was in very active vegetation.

The broom (Plate I.) was of large dimensions, measuring 15 feet in circumference and quite 4 feet in height. This large size, in conjunction with its bushy growth and vivid green colour when in foliage, made it a conspicuous object when seen from a distance. It had diverted to itself the greater share of the supplies, so that the parts above it were stunted. The leader was only about four feet in height above the point of origin of the broom, and was so slender that it had been broken across in some storm a few years ago and was hanging down on the east side in a moribund condition, still attached, however, by a band of wood and bark, showing in section a few imperfect rings and some attempt at occlusion. A branch having a common origin with that which bore the broom was also depauperised. It was, however, quite normal, except that it showed *Peziza* disks and geniculate needles. A lateral of the same whorl, but arising on the opposite side of the axis, was growing vertically as a leading shoot, and had attained to a height of 10 or 12 feet, and a thickness in proportion. Just beneath the origin of this leader, the axis was badly cancerous, as evidenced by the copious development of *Peziza* disks.

The tree was about sixteen years old, and the broom development evidently commenced in a lateral bud about the seventh or eighth year. The branch was 5 feet from the ground, and at that height the trunk measured

18 inches in circumference. The branch formed an angle of 90 degrees with the axis, and then bent gently upwards through 8 inches to the vertical. It showed a clear unbranched handle 9 inches long and 7 inches in girth, increasing to $7\frac{3}{4}$ inches, when it forked into two branches, one on the east, the other on the west side. The east branch, forming about half the broom, was dead; the west half was in vigorous growth.

A special feature of the broom was the remarkable development of long shoots, far in excess of the number usually formed on the normal branches. Other characters were the marked negative geotropism of these shoots, the decay of their apices in the autumn, and lastly, the excessive development of dormant buds. These features, in conjunction with the numerous long needles on the long shoots, gave the broom a particularly well clad appearance.

The broom-bearing *Picea* has not been planted out, but allowed to remain in the nursery, on account of its remarkable malformation. The tree (Plate II.) is a little over six feet in height, and is fourteen years old. The broom, which originates three feet from the ground, apparently began to develop when the tree was in its eighth year. Since then, it has absorbed the larger part of the supplies, dwarfing the growth of the parts above. Below it, the axis has a girth of $6\frac{1}{2}$ inches, while immediately above it is disproportionately small. The broom extends quite around the main stem, and has a circumference of 5 feet. Its shoots are hypertrophied to a marked extent, there being an excessive development of bark, the outer layers of which are of a fine, dark red colour. Dormant buds have developed so copiously that the lateral shoots stand in close set rows, mutually compressing each other laterally, while the leaves developing on the innermost twigs are contorted and etiolated.

This crowding together of branches gives the broom such a dense character that pieces have to be hewn out in order that one may get at the details of structure and origin. Another result of the mutual pressure of the branches is the masking of the negative geotropism, so usual a character in brooms. The shoots do show to some extent this character however, inasmuch as they

incline outwards and upwards, and not strictly horizontal as ordinary lateral branches of *Picea* do. The dorsiventiality, so marked owing to the habit of the branches and leaf arrangements of ordinary shoots, disappears in the broom shoots, in so far as the leaves are concerned, but is retained to some extent in the branching. The leaves show a radial disposition around the free apices of the ascending shoots, while the lateral branches arise generally in two rows right and left, and so crowded, as already mentioned, that they mutually compress each other.

The leaves show structural variations from the normal, *e.g.* in external shape, anatomy of the stomata, disposition of the stomatal bands, arrangement of the lignified tissues, as well as variations and peculiarities in the degree of lignification.

My two other brooms occur on an ash (*Fraxinus excelsior*, L.) and a thorn (*Cratægus Oxyacantha*, L.) respectively. The former I came across accidentally some years ago while botanising in the west of Fife; my acquaintance with the latter I owe to the kindness of Mr. Duff, forester to the Earl of Elgin, on whose estate in the west of Fife it occurs.

So far as I can discover, these are the first recorded cases of brooms on either of these trees. On the privet and the lilac, members like the ash of the Oleaceæ, brooms induced by the attacks of Gallmites are well known; while on allies of the thorn, brooms are more familiar still, notably those on the cherry, caused by the agency of exoascous fungi.

The ash in question here grows by the side of the public road, in a field of somewhat stiff clay soil. At breast-height it has a girth of 45 inches, and it branches at about seven feet from the ground. The first seven branches, all on the south side of the tree, are mere dead stumps; the eighth branch on the same side, 11 feet from the ground, bears the broom. At this point the trunk is 29 inches in circumference. A little higher up, but on the opposite side, a large branch arises which forms the greater part of the north side of the tree, and which apparently is also infected, as it shows broom characters, though not so pronounced as in

the smaller broom on the lower branch. The latter makes an angle of 45 degrees with the trunk of the tree, and up to the point of origin of the broom, a distance of 5 feet 8 inches, it is well developed, being 12 inches in girth where it gives off the vertical broom axis. The broom axis is 8 inches in circumference, and the broom itself is 6 feet high and of proportional spread.

The broom shoots show the characteristic negative geotropism, great development of dormant buds, and consequent "twigginess." These twigs develop in spring as long shoots, and in autumn die back for three-quarters of their length, collapsing and turning black like a frosted herbaceous shoot. Young and old shoots are markedly brittle. Neither flowers nor fruit have ever been noted on this broom. Its close branching and bushy character render it conspicuous when seen either in the leafy or leafless condition.

My first opportunity of examining the broom on the thorn was during the spring of this year, before the buds had burst. I found, however, an unexpected feature, viz. that this broom flowers. This was evidenced by the discovery of a few of last year's fruits still adhering to the twigs. This point, contrary to all experience of brooms hitherto (Tubeuf, *loc. cit.*), I was able to confirm on a subsequent visit, when I found the broom shoots bearing a number of flowers; the quantity, however, was inconsiderable as compared with that produced by a normal branch of equal size.

The thorn was one of those very old specimens that are so common in parts of Fife, forming close rows between adjacent pasture fields. No doubt an ordinary trimmed hedge originally existed, which had been cut down, and the shoots afterwards were allowed to develop from the stumps, ultimately attaining tree dimensions.

Here branching occurred at the ground-level, and two bare shoots, one on the east and the other on the west, extended upwards for 12 feet, where each branched. At 14 feet from the ground the west stem (then 12 inches in girth) gave origin to a lateral branch, at a point 10 feet along which there was produced a broom. The east stem

also had a similar broom-bearing branch, which was weaker, and originated nearer the ground.

In each case, the apical part of the branch beyond the point of origin of the broom was stunted and dead. These brooms resemble very closely the familiar pendulous brooms of the birch. By their weight the branches were depressed to within 5 feet of the ground.

The similarity to those on the birch was further seen in the close branching, death of the terminal twigs, great development of buds, as well as in the brittleness of the branches. The better developed of the two brooms, that on the west branch, was 2 feet in length and 4 feet in girth. In consequence of the pendulous character, growth was unilateral, the twigs on the exposed side being in active growth, while those on the other, the under or shaded side, were either dead or dying.

NOTES ON THE GERMINATION OF THE WINTER BUDS OF HYDROCHARIS MORSUS-RANÆ. By JAMES A. TERRAS, B.Sc., Lecturer on Botany, Edinburgh.

(Read 14th June 1900.)

Light has for a considerable time been recognised as an active factor in promoting the germination of certain seeds, the most familiar case being, perhaps, that of the mistletoe, which is said to be incapable of germination in darkness.

Stebler (1) pointed out in 1881 that the same peculiarity characterises, to a certain extent, the seeds of two grasses, viz. *Poa nemoralis* and *P. pratensis*; while in 1898 Dr. Adolph Cieslar (2) added to these the seeds of *Agrostis stolonifer* and *Nicotiana macrophylla*.

More recently, E. Heinricher (3) has called attention to the occurrence of a similar phenomenon in the seeds of *Veronica perigrina*, the germination percentage of which he gives as 75 in light, as compared with 1·6 in darkness. He also shows that the rays which are most active in bringing about these changes belong to the yellow part of the spectrum, while in blue light the germination percentage is nearly as low as in darkness, and, moreover, that germina-

tion takes place in light equally well in the absence of carbon dioxide.

A number of similar observations have from time to time been made by various authors with regard to the spores of ferns, and the whole subject of the conditions underlying the relations between light and the germination of cryptogamic spores was carefully investigated in 1893 by Forest Heald (4), in whose paper full references will be found to the earlier literature. He was able to prove that, under ordinary conditions of temperature and nutrition, the spores of ferns do not, as a rule, germinate in darkness or in blue light, although, when the temperature is raised, germination may take place independently of illumination, and his experiments showed that at a temperature of 32° C. germination occurs regularly in darkness within sixteen days.

He devoted his chief attention, however, to mosses, the spores of which, when supplied with ordinary inorganic food materials, were found to be incapable of germination in darkness or in blue light, while the only effect of raising the temperature to 32° C. was shown in a considerable retardation of germination, which, however, always took place when, at the close of the experiment, the spores were exposed to the influence of normal illumination at ordinary temperatures. A temperature of 35° C., however, proved fatal in four days. When, on the other hand, a small percentage of peptone or glucose, either together or separately, was added to the normal inorganic culture solution employed, germination took place as freely in darkness as in light; and, in some cases, the growth was even more vigorous in darkness with, than in light without, organic food.

As in the case of seeds, these spores germinated under the influence of light independently of the presence of carbon dioxide in the atmosphere, showing that the effect of illumination cannot be accounted for along the lines of a photosynthetic formation of carbohydrate substances set up by its action on the chlorophyll always present in ripe moss spores.

The spores of *Marchantia* behaved in the same way as those of the higher bryophytes, while, on the other

hand, those of *Equisetum* germinated equally in light and in darkness.

Passing from this brief historical outline, we now turn to the subject with which we are more immediately concerned.

Hydrocharis Morsus-Ranæ, as is well known, propagates very freely in a vegetative manner, by means of subaqueous runners arising in the axils of the lower leaves, and bearing at their free extremities buds which at once develop into new plants. These, as soon as their first leaves have been expanded, and long before separation from the parent, produce new runners, which repeat the process so rapidly that in a short time a considerable area becomes entirely covered with young individuals, all united to one another and to the original plant by more or less elongated branches. This process of vegetative propagation is continued throughout the whole of summer, but in autumn the buds at the extremities of the last formed runners cease to give rise directly to new plants, and undergo structural modifications of such a nature as to enable them to serve as resting organs. The axial portion becomes greatly thickened, and although the protective stipular appendages of the outer leaves are as fully developed as in the summer buds, the leaves themselves, and especially their laminar portions, remain in a rudimentary condition.

Large quantities of food materials are stored in the swollen stem, and its cells become crowded with small compound starch grains, each composed of three or four individuals arranged in a tetrahedral manner. That, however, no soluble carbohydrates are present, may be assumed from the failure to obtain any reaction with α-naphthol sulphuric acid, or with thymol sulphuric acid, until sufficient time has elapsed to allow of the acid setting up hydrolysis of the starch, etc.

No oils or resins are distinguishable, and no aleurone grains or solid reserve proteids can be recognised, but all the cells are completely filled, in so far as they are not occupied by starch, with a clear, somewhat refractive fluid, which, as it entirely and at once disappears from cells injured in the process of section cutting, is apparently freely soluble in water. When, however, thick sections,

or the entire buds, are heated to the boiling-point in water it coagulates, forming either a single greyish finely granular mass, enclosing the starch grains and filling the cell, or two or three small, rounded, drop-like aggregations among which the starch grains are distributed. It is coagulated in a similar manner in buds which have been preserved in alcohol, as well as in thick sections treated with mercuric chloride, chromic acid, or Millon's reagent, with the last of which, however, it only gives a greyish yellow tint, though with nitric acid and ammonia a very marked xanthoproteic reaction is obtained. We may therefore conclude that the reserve proteid takes in this case the form of a fluid albumin similar to that described by Bokorny (5) as occurring in certain seeds and green parts of plants.

As soon as they are fully ripe the buds separate from their runners and sink at once to the bottom of the water, where they rest till the following spring, when they rise to the surface and develop at once into young plants. It not unfrequently happens, however, that during winter some of the buds become buried to a depth of an inch or more under the mud at the bottom, and should this be disturbed at any period during the following summer or autumn they may be found still in their resting condition and showing no signs of germination.

The same result may be obtained artificially by covering buds with about an inch of soil in a flowerpot, and sinking the whole overhead in a vessel of water.

In this way buds may be kept in their resting condition for at least two years, the length of time during which experiments have been carried on, but, as at the end of that period they are still perfectly fresh and germinate at once on removal from the soil, there seems no reason why they should not retain their vitality very much longer.

The utility of this capacity for continued quiescence to a plant, which like *Hydrocharis* lives naturally in ditches and shallow pools liable to prolonged periods of drought, is in itself sufficiently obvious, but is rendered even more striking by the very considerable degree of desiccation which these buds are able to withstand while in the resting condition,—they may in fact be kept air dry in an

open dish for at least two months during winter without in the least affecting their power of germination, though if this process has commenced in the smallest degree, even a very short period of dryness is sufficient to kill them.

That the layer of mud under which the buds require to be buried acts merely as a screen, cutting off the light rays, may safely be concluded from the fact that when buds in a vessel of water are protected in any other way from the action of direct illumination, as, for example, by enclosing the vessel in a metallic case, germination does not take place until they are again exposed to light.

Intense illumination, such as bright sunlight, is not necessary for germination, as this process goes on freely, though somewhat more slowly, in diffused light, such as that supplied by a north window. On the other hand, the minimum degree of illumination below which germination will not take place is far removed from absolute darkness, and buds will remain unchanged for long periods if merely shaded from direct light, or kept at a considerable distance from a window.

With the intention of approximately determining what particular rays exert the greatest influence in bringing about germination, use was made of a series of coloured screens, composed of aqueous solutions of various inorganic salts. The following were found most suitable, and were all carefully tested spectroscopically:—

1. A solution of ferric thiocyanate, of such a strength that only light of wave lengths between 670 $\mu\mu$ and 715 $\mu\mu$ was able to pass through a thickness of 20 mm. It thus transmitted only the deep red.
2. A dilute solution of the same salt, which transmitted all the rays between 570 $\mu\mu$ and 715 $\mu\mu$, *i.e.* most of the red, all the orange, and part of the yellow.
3. A saturated solution of potassium bichromate, which allowed all the rays between 522 $\mu\mu$ and 715 $\mu\mu$—*i.e.* nearly all the red, the orange, yellow, and a trace of green—to pass.
4. A saturated solution of nickel sulphate, which transmitted rays between 422 $\mu\mu$ and 616 $\mu\mu$, *i.e.* the blue-violet, bright blue, green, yellow, and a little orange.

5. A dilution of the well-known ammonio-cupric sulphate solution, of such a strength as to transmit rays from 400 $\mu\mu$ to 533 $\mu\mu$, *i.e.* the violet, blue-violet, bright blue, and green.
6. A strong solution of the same substance, which cut out all the rays except those between the 400 $\mu\mu$ and 480 $\mu\mu$.

Under the strong solution of ferric thiocyanate no germination whatever took place within three weeks, though the weak solution allowed the buds to germinate freely; showing that, while deep red light does not promote germination, the orange and yellow rays are effective in this direction. The strong ammonio-cupric sulphate fluid also prevented germination, while this process took place but slowly in the dilute solution; showing that, while the violet and deeper blue rays have no effect on germination, the lighter blue, and especially the green, promote this process, though only to a small extent.

Both potassium bichromate and nickel sulphate allow germination to proceed almost as rapidly as in daylight, so that the yellow and orange rays are apparently the most active, though the green and lower red have also a certain effect,—results which agree closely with those obtained by Forest Heald, who used only strong ammonio-cupric sulphate and potassium bichromate.

Light is, however, not in itself sufficient, but a certain degree of heat is also essential for germination, and the minimum in this case seems to lie not far below 10° C., as at a lower temperature the buds do not germinate, whatever be the intensity of the illumination to which they are exposed, while the maximum is to be found between 35° C. and 40° C., above which they are rapidly killed. Heat, however, apart from light, is quite incapable of inducing any change in resting buds, as is shown by the following experiments, undertaken with the object of producing germination in darkness by artificial means.

For this purpose buds were incubated in darkness at temperatures of 25° C., 30° C., and 35° C. for three weeks, but showed at the end of that period no trace of germination, and as exposure to 40° C. for forty-eight hours invariably proved fatal, a temperature higher than 35° C.

could scarcely be employed with any hope of success. The three lower temperatures, viz. 25° C., 30° C., and 35°C., had however no harmful effect, as, after exposure to them for the above-mentioned period, all the buds germinated normally in light at the ordinary temperature, without any appreciable retardation, giving a series of results quite comparable with those obtained by Forest Heald in the case of moss spores, which, however, were killed at a slightly lower temperature, viz. 35° C.

With the same object in view, buds were kept in darkness, at the ordinary temperature of the room (between 10° C. and 15° C.), in normal inorganic solution containing low percentages of the following organic food materials, each being used at strengths of 1, 2, 5, and 10 per cent. respectively :—

Nitrogenous substances—Peptone, Carbamide, Asparagine, Glycocoll.
Carbohydrates, Aldohexoses.—d.-Glucose, d.-Mannose, d.-Galactose.
Ketohexose.—d.-Fructose.
Disaccharoses.—Cane Sugar, Maltose, Lactose.

Care was taken to sterilise all the fluids by repeated steaming, while the buds before being placed in the tubes were rapidly washed in a one-tenth per cent. solution of mercuric chloride and at once rinsed several times in sterilised water. No indication of germination was, however, observable in any of the tubes at the end of the three summer months of June, July, and August during which the experiment was continued. In all cases, buds formed in the previous year were employed, and at the close of the experiment were kept in fresh water till the following spring, when they all without exception germinated as freely as normal buds of the preceding autumn.

As the buds contain in general a considerable amount of chlorophyll, it seemed possible that a photosynthetic absorption of carbon dioxide might be essential to germination, though this possibility was to a considerable extent discounted by the appearance, as above mentioned, of similar phenomena in seeds which contain no chlorophyll, and by the want of agreement between the spectral position of the rays which promote germination and those which initiate photosynthesis, as well as by Forest Heald's results with moss spores.

The following methods were, however, employed to determine this point for *Hydrocharis* buds :—Test tubes, containing ordinary tap water and drawn to a narrow neck, were boiled in a steam jacket for several hours to expel any dissolved gases, they were then connected, while still hot, with a series of potash bulbs by means of a rubber stopper, and allowed to cool slowly, so as to prevent too rapid an inrush of air. When quite cold, buds were dropped into the upper parts of the tubes, a current of air freed from carbon dioxide was drawn through the apparatus by means of an aspirator, the buds shaken down into the body of the tube, and the whole sealed at the blowpipe.

As only tubes of a considerable size (10 in. long by $1\frac{1}{4}$ in. diameter) were employed, and these were only partially filled with fluid, a sufficient supply of oxygen was always left for the respiration of the plants, and in every case germination proceeded as under normal conditions.

Cultures in larger vessels treated in a similar manner to get rid of the dissolved gases, but left freely open to the atmosphere through long tubes filled with soda lime, which, while permitting the free passage of oxygen, prevented the entrance of carbon dioxide, gave exactly similar results.

That, as might be expected, germination does not take place in the absence of oxygen may easily be proved by treating a flask, as above described, to expel all the dissolved gases, and then allowing it to cool in an atmosphere of carefully washed hydrogen. When cold, buds are introduced, and any air which may have entered at the same time is expelled by means of a rapid current of gas, continued for a few minutes, and the flask then sealed—no trace of germination is observable either in light or darkness,—and after the elapse of some days the buds will be found to be dead, showing that in this, as in other cases, respiration is essential to germination, with the necessary result that a certain amount of carbon dioxide must be set free during the process. With the object of obtaining some insight into the influence of illumination on the respiratory process going on in these buds before and during germination, a method was sought for by which some indication might be obtained regarding the excretion of carbon dioxide during the periods in question, and after some preliminary

experiments the employment of a modification of the phenolphthalein method, suggested by Klebs (7) in connection with certain algæ, and recommended by Professor Balfour (7) as a lecture experiment, was decided on.

Tubes were prepared in the same way as those used in the experiments on germination in the absence of carbon dioxide, but with this difference, that they contained traces of phenolphthalein, which imparted to the fluid a bright rose tint. Such solutions retain their colour unaltered so long as their reaction remains faintly alkaline, but so slight is the degree of alkalinity due to the trace of lime always present in ordinary tap water, and from which the carbon dioxide has been driven off in boiling, that the amount of this gas absorbed from the atmosphere during the process of cooling is frequently sufficient to produce complete decoloration. When, however, the tubes are cooled in the absence of carbon dioxide, and, after having been charged with carefully washed buds, are finally sealed, any degradation of tint which may take place must be due to the carbon dioxide given off by the buds during the process of respiration; and the rate of decoloration, as compared with that in a control tube containing no buds, will be a measure of the amount of carbon dioxide formed.

By this means it is easy to prove that, as might be expected, the buds respire to a slight extent during winter, both in darkness and light, and also that the rate at which this takes place is unaffected by illumination, while even in summer the speed of carbon excretion is not greatly increased so long as they are not exposed to the action of light, though the unavoidable rise of temperature must to a certain extent hasten the process.

That, however, the increase due to this cause is at best very small is shown by a comparison of two tubes, both of which were protected from light, while one was incubated in a thermostat at a temperature of 35° C., and the other remained at the temperature of the room (about 10° C. to 15° C.). The experiment was continued for ten days, and although decoloration took place in the warmed tube slightly sooner than in the cool one, the acceleration due to even so considerable a difference of temperature was not very marked.

The enormous respiratory acceleration which normally accompanies the germination of resting organs is, however, made very obvious by the rapid decoloration of the fluid which takes place when a tube containing buds is exposed to light. A comparison of such a tube with a control tube containing an equal quantity of the same fluid, and an equal number of buds, of as nearly as possible the same size, and kept under identical conditions, but in darkness, shows that while at first the effect of illumination in accelerating carbon excretion is but small, as the contents of both tubes remain almost identical in tint for the first twelve hours, an enormous increase soon takes place in the amount of carbon dioxide formed, as is made apparent by the rapid decoloration of the illuminated tube, the fluid in which is generally entirely bleached within forty-eight hours, while the rose-red tint is still recognisable in the protected tube at the end of a week, and decoloration is seldom complete till after the elapse of from eight to ten days.

Exactly similar phenomena occur in flasks prepared in the same way, but left freely open to the atmosphere through the medium of soda lime tubes, which protect the contained fluid from the entrance of atmospheric carbon dioxide, showing that the somewhat limited volume of oxygen contained in the sealed tubes cannot in any way affect the process.

No increase of carbon excretion is, however, shown in the case of buds enclosed in an atmosphere of pure hydrogen, where intramolecular respiration alone is possible, and in such cases decoloration takes place even more slowly than in darkness, while not unfrequently the buds die before that process is complete.

That this loss of tint in the phenolphthalein solution is due to carbon dioxide, and not to the formation of any organic acid by the buds, is easily proved by re-boiling a tube which has been opened after complete decoloration, when the original tint gradually returns as the carbon dioxide is driven off.

During germination the proteid substance contained in the cells of the bud seems to be but little, if at all, affected, as the xanthoproteic reaction is almost as well

marked at the close of germination as at its commencement; while, on the other hand, the carbohydrate stores are entirely used up and disappear, pointing very clearly to the presence of diastase in the germinating bud.

Fully germinated plantlets dried at 40° C., powdered and macerated with a 1 per cent. solution of soluble starch at 45° C. for several hours, invariably gave a slight reduction with Fehling's solution, showing that a small but recognisable amount of diastase was then present in the plant; while, on the other hand, no evidence could be obtained of the existence of this ferment in the resting buds.

As Professor Green (5) has shown that the production of zymase (diastase) from the zymogen of saliva is facilitated by the action of the less refrangible rays of the spectrum, it seemed possible that at least a partial explanation of the influence of light in the present case might be found in a similar production of diastase from a zymogen pre-existing in the buds; when, however, these were killed by drying at 40° C. powdered, mixed with distilled water, to which a little thymol had been added as a preservative, and exposed to bright sunlight for periods varying from one to three weeks at the ordinary temperature, no reduction was obtainable with Fehling's solution, even after prolonged incubation of the mixture with an equal volume of 2 per cent. starch solution, showing that no diastase is formed during the experiment.

It would seem, therefore, that the diastasogen itself is not yet formed in the resting state, but probably owes its origin to an action of the light antecedent to that by which the diastase is formed from it.

All the evidence thus points to the influence of light as in some way facilitating the nutrient processes essential to germination, and if, as seems probable, we are justified in regarding the increased respiration as the outward expression of an increased liberation of carbon atoms from the proteid molecule, and therefore of increased assimilation of carbohydrate from the stored up starch, we may conclude that the primary effect of incident illumination is not, at least in this case, the mere chemical production of a zymase from an already formed zymogen,

but rather, at least in its more important aspects, the stimulation of the protoplast to an increased vital activity leading up to the development of the zymogen itself, which, in its turn, under the influence of the same rays, becomes converted into a zymase, by which the absorption of the stored food materials is rendered possible.

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Notes on the Potentilleæ. I.—The Flower. By R. A. Robertson, M.A., B.Sc. (With Plates.)

(Read 12th July 1900.)

On account of their variability, the *Potentillas* have always been a confusing group, and the statements made by systematists as to the number of species differ widely. Nestler ("Monographia de Potentilla") in 1816 enumerated 68 species, and varieties in addition. The shapes of the leaves and the characters of the torus were utilised for the subdivisions of the group. In De Candolle's "Prodromus" (1825), the genus *Potentilla* is included in the tribe Dryadeæ of the Rosaceæ. 106 species, besides sub-species and varieties, are described. The genus is subdivided into three sections, based on such characters as the colour and shape of the petals, as well as the manner of branching of the foliage leaves.

In Lehmann's "Revisio Potentillarum" (Nov. Act. xxiii. Supp., 1856), 204 species, and many varieties, are minutely described. Here the genus is elaborately subdivided—primary characters being derived from the general habit, branching of the leaves, and the inflorescence axes, with the position of the individual flowers. For the ultimate divisions, characters are derived from the carpels—glabrous and villous,—and the colour and shape of petals.

Bentham and Hooker ("Genera Plantarum," 1865) include the genus, along with *Dryas*, *Geum*, *Fragaria*, and others, in the tribe Potentilleæ of Rosaceæ. 120 species are admitted, but it is pointed out that the great variability of the group has led to the number of species being raised to 220 by other authors.

By Baillon ("Nat. Hist.," 1871) they are placed in the same series as *Fragaria*, *Sibbaldia*, *Rubus*, *Geum*, and *Dryas*. He gives 250 as the figure for the species, but remarks that this should be reduced by one-third.

Eichler ("Bluthendiagrammen," 1878) includes them in the same tribe as the Rubeæ.

Schimper ("Text Book of Botany," 1894) follows Eichler, forming of them, along with *Fragaria*, *Rubus*, etc., the sub-family Ruboideæ. Warming ("Systematic Botany," 1895) repeats Bentham and Hooker, including the genus with *Comarum*, *Fragaria*, *Geum*, and *Dryas* in the tribe Potentilleæ. Since Lehmann's "Revisio" was published new species are described, so that if there is a tendency to contract the group on the one hand by amalgamating old species, it is being slowly added to on the other by the discovery or manufacture of new forms.

It was on purpose to ascertain whether there might not be some features in the minute anatomy that might serve as auxiliary character for purposes of classification that this study of the anatomy of the group was entered upon. It was begun on the suggestion of Dr. Macfarlane, and material was supplied, at first, from the Botanic Garden, Edinburgh, to the Regius-Keeper of which I take this opportunity of tendering my best thanks. Subsequently researches were made on material grown from seed supplied by Prof. Cornu, of the Jardin des Plantes, Paris, to whom also I express my indebtedness.

In the course of the examination the inflorescence axes have been studied, and the leaves and epidermal appendages. In regard to the latter, if one exclude the pilose papillæ of the petals, the hairs are of two kinds—(*a*) thickwalled, conical, usually unicellular, with a bulbous base often partly ensheathed by a rosette of epidermal cells: and (*b*) multicellular, capitate, glandular hairs, similar to those of the Primulaceæ. The glandular head is usually of a single cell, but may be bicellular, with the septum vertical. One or both kinds of hairs may occur on the surfaces, margins, and apices of the leaves, on the axes of inflorescence, and on epicalyx and calyx segments. On the torus only the unicellular hairs occur, and these also it is which form the barrier ring over, and internal to, the nectaries.

In addition to the general anatomy of the flower, the minute structure of the various parts has been studied, as well as the mature achenes, and the seedlings at various stages.

In the following account of the flower, chiefly those points are dealt with which appear to be of value for purposes of classification.

The flowers may be solitary, but are frequently grouped into somewhat open inflorescences composed of dichasial cymes arranged on a primary racemosely branched axis.

In section, the flower shows a shallow concave torus shaped liked the bottom of a bottle, with a solid core. The periphery bears a circle of green segments, usually five in number, forming the epicalyx: each of these segments has been described as composed of the two fused stipules of adjacent sepals—this because the epicalyx segments may bifurcate. Examination of the developing flower, and of the vascular supply of the adult segments, cause me to differ from this commonly accepted view, and regard the epicalyx segments as integral units as much so as each sepal in fact is.

Characters of the epicalyx of use for systematic work are the relative length of the segments; they may be longer or shorter, narrower or wider than the sepals. Again, their margins may be minutely toothed, each tooth topped by a hair, and occasionally having a water-gland.

The character and distribution of the hairs, and the shape of the apex are variable. Thus the latter may be acute, acuminate, or bifid, or even trifid, from the appearance of two large lateral teeth some little way down. Each segment (Fig. 1, *ep.*) has a main rib and two smaller laterals, which converge apically and form a vascular fan communicating with a water-gland.

This water-gland usually occupies a shallow dimple on the upper surface of the leaf, and has several water-stomata; its position is indicated by a red coloration of the segment apex.

The *Calyx* consists of four or five sepals of a similar structure to the epicalyx segments, and alternating with them. The same variation in the epidermal appendages and their distribution occurs, the hairs being frequently longest along the line of the ribs, especially the main ribs. The vascular supply (Fig. 1, *sep.*) is by three main ribs, the two laterals anastomising with those of the adjacent epicalyx segments.

All three converge apically, and meet under a water-gland having similar structure and distinguished by a similar colour as in the epicalyx segments. This coloration, indicating water-glands, is found at the apices and teeth of the ordinary leaves also. The æstivation of the sepals is valvate.

In the upper mesophyll cells of the sepals and epicalyx segments are enormous quantities of oxalate of lime in rosette crystals.

Both epicalyx and calyx are persistent, and enclose the mature fruit.

The *Corolla*, in colour, white, yellow, or red, or some combination, is of four to five petals alternate with the sepals. The petals vary in shape, perhaps the commonest is the obcordate; each has a very short claw which joins the torus by a very constricted neck. Their upper surface bears the usual petaline pilose papillæ, and their epidermal cells have a wavy sinuous outline; their size in relation to the sepals varies, being larger or smaller—sometimes half the size, at other times almost double the size. In consequence of their constricted claw they fall off very readily. Their vascular supply is derived from the main

trunk that supplies the epicalyx segment to which each petal is opposite (Fig. 12, *p.v.s.*).

Andrœcium. — According to Payer (Traité d'organ. comp. de la fleur.) this is either isostemonous with five stamens opposite the sepals (*Sibbaldia*), or opposite the petals (*Chamærhodos*), or diplostemonous, with one whorl superposed to the sepals, and another to the petals (*Horkelia.*) Further, diplostemony may arise by deduplication, ten stamens being found in a single whorl in pairs, superposed either to sepals or petals.

Dickson's studies on the stamens of the Rosaceæ are found in "Journ. of Bot.," vols. iii. and iv., and "Trans. Bot. Soc.," vol. viii. In the latter he points out that the andrœcium of the *Potentillas* is arranged in the form of a series of festoons stretching from petal to petal, each festoon being concave externally. He regarded the andrœcium as composed of five compound stamens, the terminal lobe of each developed as a petal so called, and the lateral lobes as fertile stamens. Where a stamen is exactly superposed to a sepal, he regarded it as stipular in character—an interstaminal lobe,—bearing the same relation to the compound stamens on either side of it as the epicalyx segment does to its adjacent sepals. Dickson examined the andrœcia of twenty-nine species, and founded three types thereon of staminal arrangement.

Type 1 had twenty stamens arranged in five festoons of three each, and five single oppositipetalous stamens. This is the commonest type among the Rosaceæ; it occurs, for example, in *Fragaria* and *Comarum.*

Type 2, with thirty stamens arranged in five festoons of five, and five oppositipetalous stamens. This occurred in three species.

Type 3, with twenty-five stamens in five festoons of five. This occurred in two species—*P. fruticosa*, L.; and *P. rupestris*, L.

Dickson emphasised the great importance of these staminal arrangements in establishing, or at least limiting, minor groups. My observations confirm the above, and enable me to indorse Prof. Dickson's remarks regarding the classificatory importance of the staminal arrangements.

I have had opportunities of examining sixty-five species, including twenty of those examined by Dickson. Some of these fit into Dickson's three types, but the remainder form three new types of arrangement, which I number 4, 5, and 6 respectively.

Type 4 (Fig. 4) has twenty-five stamens in five festoons of four, and five solitary oppositipetalous.

Type 5 (Fig. 5), with twenty stamens arranged in five festoons of four each.

Type 6 (Fig. 6), with fifteen stamens arranged in five festoons of three each.

In the following list is indicated the type of staminal arrangement in each species examined. The number in front of each species is that in Lehmann's "Revisio." The list contains all those I have examined, with the exception of those previously described by Dickson ("Trans. Bot. Soc.," *lcc. cit.*), and some that were doubtful. It is interesting to note here that my specimens of *P. rupestris*, L., showed the arangement in Type 5, while that of Dickson exhibited his Type 3.

29. P. Ornithopoda, Tausch.—I.
32. P. Verticillaris, Steph.—IV.
53. P. rupestris, L.—V.
60. P. bipinnatifida, Dougl.—IV.
60. P. Agrimonioides, M.B.—I.
60. P. Arachnoidea, Dougl.—IV.
64. P. Chinensis, Ser.—I.
P. Drummondii.—IV.
69. P. approximata, Bge.—IV.
89. P. Kotschyana, Fenzl.—III.
91. P. laciniosa, W.K.—IV.
P. erecta.—II.
92. P. læta, Rchb.—IV.
P. pedata.—I.
96. P. desertorum, Bnge.—I,
101. P. Fenzlii, Lehm.—I.
105. P. Collina, Wib.—I.
106. P. canescens, Bess.—I.
108. P. intermedia, L.—I.
109. P. mollissima, Lehm.—VI.
112. P. Detomasii, Ten.—III.
116. P. kurdica, Boiss.—I.
P. salisburgensis.—I.
138. P. pilosa, Willd.—IV.
P. alchemilloides.—I.
153. P. Cathaclines, Lehm.—IV.
P. insigne.—I.
172. P. Hookeriana, Lehm.—IV.
199. P. Norvegica, L.—VI.
P. Schrenkiana, Rgl.—IV.
P. Iberica, Hort. Pars.—I.
P. Ontopoda, Dougl.—I.
P. Buccoana, Clem.—I.
P. Macnabiana.—I.

Dickson describes the development of the festoons as centripetal, *i.e.* the terminal lobe of the compound stamens—the petal—appears first, then the lateral lobes in basipetal order on either side. The oppositipetalous stamen, when present, develops late. He figures this condition in *P. fruticosa* ("Trans. Bot. Soc.," *loc. cit.*, Fig. 5) which has Type 3 staminal arrangement. In contrast to

this I find in *P. Schrenkiana* (Type 4 staminal arrangement) that the staminal papillæ of each festoon may develop simultaneously.

Fig. 2 shows a young flower of this species bisected in the antero-posterior plane. The epicalycine, calycine, and petaline papillæ are developed, but there is as yet no trace of the staminal papillæ. Points to be noted in this figure are the relatively large size of the epicalycine papillæ at this early stage—a feature which would in some degree support the view of the morphological nature of the epicalyx suggested in this note. Another interesting point is the close relation of the petaline to the epicalycine papillæ, the former being practically outer growths or branches of the latter.

By the time that the staminal papillæ are all represented the epicalyx and calyx segments are of large size, and, arching inwards, form a funnel-shaped covering over the centre of the flower; the throat of the funnel is closed by a considerable growth of hairs from the inner surfaces of the segments. These hairs develop very precociously, rudiments of them being found at a very early stage on the papillæ. It is only now that the carpellary papillæ begin to appear on the hitherto smooth hemispherical surface of the gynophores. The full details of development of the various types of flowers, and also the discussion as to the nature of the corolla, suggested by its manner of development are reserved for a future note.

Each stamen (Fig. 9) is composed of a free filament tapering towards its apex, where it bears a sub-sagittate anther, the lobes of which converge apically and diverge basally. The filament (Fig. 10) has a single central bundle surrounded by a loose cylinder of parenchyma, the cells of which increase in size, progressing outwards to the epidermis. The anther lobes are two in number in the immature stamens (Fig. 11), and the dehiscence is longitudinal and sub-lateral. The anther wall consists of two layers, an inner fibrous and an epidermis. Where the epidermis dips into the connective between the anther lobes on the posterior and anterior faces, its cells are much elongated radially, and contain a pigment which stains deeply with hæmatoxylin (Fig. 11, *p.*).

Irregularities due to branching in the stamens are by no means uncommon—the middle third of the filament being deeply grooved medially and longitudinally on the posterior and anterior faces, and the two halves diverging as lateral branches in the upper third.

Vascular Supply of the Androecium (Fig. 1).—At the base of the toral cup a complete circular stele gives off ten strands, which pass out separately to the epicalycine and calycine segments.

From each epicalycine bundle a petal is supplied, and also the neighbouring stamen. Thus, in the figure which represents the vascular supply of a flower of Type 4, the two parapetalous and the solitary oppositipetalous stamens are so supplied, the former two by strands which branch off on either side of each epicalycine strand near its origin at the central stele; they may arise separately from the epicalycine strands, and then there appear twenty separate strands in all. The sepaline stamens are supplied by strands which come off laterally from the corresponding sepaline strand about half-way up the toral cup. Towards the rim of the cup lateral anastomoses occur between adjacent bundles, and here are situated the nectaries which are thus richly supplied.

Nectaries.—Bonnier ("Annales des Sc. Nat.," Ser. vi. vol. 8) describes the nectaries of *P. Fragaria* and *P. verna.* He states that the nectariferous tissue forms a ring; that it is composed of cells smaller than those of the surrounding parenchyma. The cells have non-granular refringent contents of a uniform yellow colour. This description does not apply to every case, as far as my observations go. A complete nectariferous ring of a chrome-orange colour exists in some species, surrounding the bases of the stamens, and extending internal to them. In other species the nectaries are five in number, lemon-yellow in colour, each consisting of a mamillated convex or shallow concave surface, internal to the bases of the petaline stamens (Fig. 1 and 12, *n.*). Further, Bonnier states that the nectariferous tissue has no distinct epidermis. I find, on the contrary, in many, an epidermis of well-marked columnar epithelial cells. These, however, are early ruptured, and the old nectaries appear to have a ragged surface.

Internal to the nectaries is a broad ring of conical unicellular hairs. These (Fig. 12, *h.*) extend outwards and upwards, and form a more or less efficiently protective barrier over the nectaries.

Gynæcium.—The gynophore (Fig. 12) is somewhat elongated, or broadly club-shaped, constricted at its point of origin from the concave surface of the torus. Its epidermis is either smooth or covered with numerous conical unicellular hairs. Its surface is raised up into blunt papillæ, each representing the point of insertion of a carpel. In consistency it is usually dry, not increasing very much in size on fruiting. *P. Comarum* is an exception to this, and forms a transition to the succulent condition of the *Fragarias.*

Vascular Supply.—The stele, after giving off the ten or twenty strands to the floral envelopes and androecium, passes on into the gynophore, where it branches into many small strands, which together form a vascular cone, with a few lateral anastomoses. From the outer surface of this network arise the small twigs supplying the separate pistils. Each twig separately passes obliquely upwards and outwards through the cortex into the carpellary stalk. The pith cells adjoining the vascular network frequently contain numerous rosette crystals of calcium oxalate.

Pistils.—These are, as a rule, very numerous, although occasionally the number is much reduced. Each (Fig. 14) has a small stalk, which is continuous with a very marked ventral keel on the ovary. Ovary, style, and stigma are well demarcated. The ovaries are roughly ellipsoidal, slightly flattened from side to side, with a distinct keel on the ventral side, which is occasionally continued as a less marked ridge around the dorsal border. The style, which arises as a continuation of the ventral keel, originates at different levels in different species, so that the distance between the actual and organic apex of the ovary varies within wide limits; and this is a point that may be of some systematic importance. Thus in some it is slightly lateral, in others more markedly so. In others, again, it may be almost basal, as in *P. rupestris,* which, in this connection, forms a link with *P. Comarum* and the *Fragarias.* Concurrent with this variability in the point of origin of the style are different degrees of anatropism of the ovule, from anatropous

to sub-anatropous conditions when the raphe is hardly marked.

The *Ovarian Wall* is usually white in colour, but becomes brown on maturing. The whole ovary also increases somewhat in size, and the style drops off on fruiting. The ovaries are usually closely packed together on the torus, and entirely concealed by the projecting basal epidermal flanges of the styles.

The ovarian wall (Fig. 3) is composed of three strata of tissue—(1) an outer parenchymatous (*p.*) of a few layers of closely packed cells, the epidermal having cutinised walls; (2) a middle crystallogenous layer (*cx.*) of small, close set, quadrangular, thickish-walled cells, each with a cubical crystal of oxalate of lime; (3) an inner sclerenchymatous stratum composed of (*a*) an outer layer of spindle-shaped fibres parallel to the long axis of the ovary, and (*b*) an inner layer of similar fibres with their long axes transverse to that of the ovary.

The *Style* is continuous with the ventral keel of the ovary, to which it is fixed by a very constricted neck. The length of the style varies, and this may be a feature of systematic importance, as there are well marked long and short styled species. It is composed (Fig. 7) of a cylinder of parenchyma filled with a loose conducting tissue of cells, rich in proteids. The parenchyma cells increase in size outwards to the epidermis, which is composed of larger cells protruding outwards, often in a papillose fashion. These cells are specially noticeable just at the base of the style (Figs. 8 and 14, *b.f.*) near the constricted neck, where they form a sort of basal flange or rosette. They are less well developed on the ventral side, hence appears a ventral groove, which is continuous with a gap in the lip of the funnel-shaped papillose stigma (Figs. 15 and 16). There is usually a more or less well marked constriction just beneath stigma.

All the outer cells of the style contain a peculiar pigment of a light lemon-yellow colour, apparently similar to that already mentioned as occurring in the connective epidermis of the anthers. It resists the usual solvents, gives a brownish precipitate with hydrochloric acid, and dissolves, after a preliminary change

of colour, on treatment with alkalies. It appears similar to that described by Claudel ("Comptes Rendus," 1889) as occurring in the cell cavities of certain seed coats, and as arising from the metamorphosis of the protoplasm.

The *Ovule*, of small size, is more or less anatropous, with the micropyle superior, and the raphe ventral. It is one-coated, and at the chalazal end a pigment having similar properties to that of the styles is developed during maturation.

Vascular Supply of Pistil and Ovule.—The single bundle (Fig. 13) that enters the stalk from the torus bifurcates right and left on passing into the ventral keel of the ovary. It may previously give off a small branch which curves round under the basal end of the ovary, but this is not frequent. The strands pass into the style when they are seen in cross section (Fig. 8, *s.v.*) in the parenchyma, right and left of the median line. They terminate in fan-shaped extremities at the constriction just below the funnel-shaped stigma. From one of the strands in the keel a bundle curves inwards through the funiculus and supplies the ovule. It courses down the raphe, and terminates at the chalaza in a small fan-shaped vascular cup. From the other bundle in the keel a similar branch curves outward over the top of the ovary and forms a small dorsal bundle of varying length.

All these bundles are composed of delicate spiral and annular tracheides, occasionally assuming the appearance of vasa. The phloem, so far as present, is represented by a few delicate-walled elongated cells, rich in proteids.

The summary of floral characters of systematic importance works out somewhat as under. In addition to such features as shape, origin, relative size and position of the epicalyx segments, sepals, and petals—characters already utilised in classification—it is suggested here that the various types of staminal arrangements, as previously partly described by Dickson, and, as further described here, may be of considerable value. Further, the more minute details of the pistils, in addition to the character of the nectaries, whether separate or confluent, are of importance. Thus, the length of the styles, character of the stigma, appearance of the external surface of the

styles, as well as the extent of the ovarian keel, and the attachment thereto of the style, are all diagnostic points.

A comparison of Figs. 17 to 23, which are outline drawings of pistils, will bear out this statement. Thus, *Hookeriana* has a short thick style less than twice the length of the ovary, of fairly uniform diameter throughout its length, expanding suddenly at the apex into a screw-nail head like stigma. *Laciniosa*, again, has the ovarian wall longitudinally ridged and furrowed; a keel all round, most pronounced on the ventral border; a marked basal contraction of the style where it joins the keel. *Rupestris* has a characteristic sub-basal insertion of the style, which is spindle-shaped, contracted at apex and base where it adjoins the stigma and ventral keel of the ovary respectively. The length of the style of the *Kurdica* is characteristic, being many times as long as the ovary, and tapering apically into a discoid stigma, its surface is mamillated. *Viscosa* has a short style again, only about one and a half times the length of the ovary, tapering apically. Further, the ovary has viscid glandular hairs.

EXPLANATION OF THE FIGURES.

1. Diagram illustrating vascular supply of flower.—*ep.* = epicalyx segments; *sep.* = sepal; *pet.* = petal; *n.* = nectary. The supply of one sepal and one epicalyx segment is shown in detail.

2. Left half of a young flower of *P. Schrenkiana.*—*e.* = epicalyx; *s.* = sepal; *p.* = petal. Leitz., Oc. 3, Obj. 3.

3. Transverse section of ovarian wall.—*p.* = outer parenchymatous layer; *c.* = crystallogenous layer; *s.* = schrenchyma layer. Leitz., Oc. 3, Obj. 7.

4, 5, and 6. Diagrams of types 4, 5, and 6 of staminal arrangements. The epicalyx segments are omitted.

7. Half of a transverse section of style in the upper third. Leitz., Oc. 3, Obj. 7.

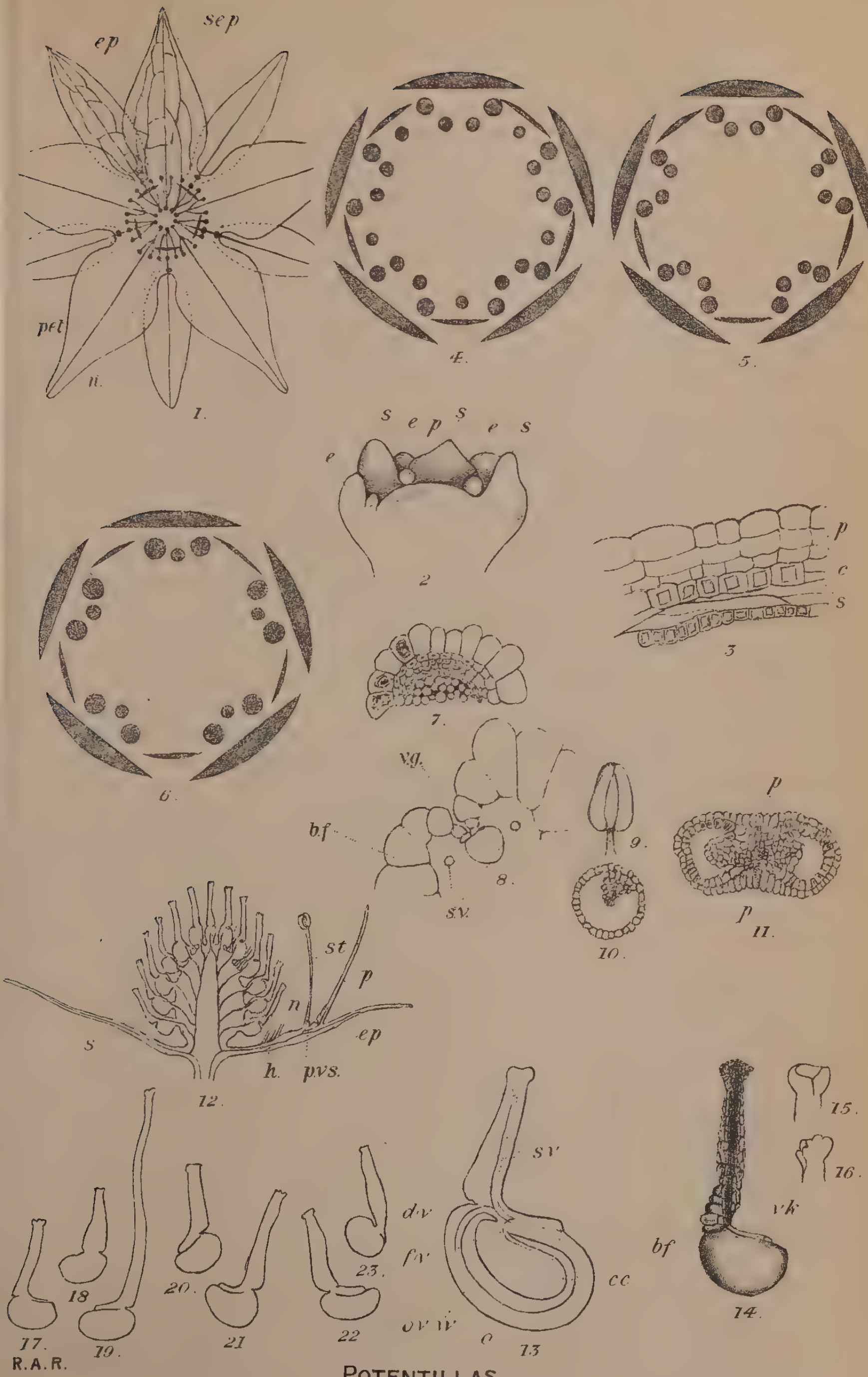
8. Half of a transverse section of style near its base.—*v.g.* = ventral groove; *b.f.* = swollen epidermal pigment cells forming basal flange; *s.v.* = stylar vessels. Leitz., Oc. 3, Obj. 7.

9. Stamen, showing anther and upper part of filament. Oc. 3, Obj. 2 in.

10. Transverse section of filament. Leitz., Oc. 3, Obj. 7.

11. Transverse section of immature anther.—*p.* = pigment cells. Oc. 3, Obj. 7.

12. Diagrammatic vertical section of flower, showing vascular supply of gynophore and pistils.—*s.* = sepal; *ep.* = epicalyx; *p.* = petal; *st.* = stamen; *n.* = nectary; *h.* = hairs; *p.v.s.* = origin of vascular bundle of petal.



POTENTILLAS

13. Diagram of vascular supply of pistil.—*o.* = ovule; *ov.w.* = ovarian wall; *s.v.* = stylar vessels; *f.v.* = funicular vessel; *c.c.* = chalazal cup; *d.v.* = dorsal vessel.

14. Pistil showing basal flange.—*b.f.* formed by expanded epidermal cells; *v.k.* = ventral keel.

15. Ventral, and 16, profile view of stigma, showing the ventral groove.

17–23. Outline drawings of pistils.—17 = *laciniosa*; 18 = *viscosa*; 19 = *kurdica*; 20 = *Hookeriana*; 21 = *Fenzlii*; 22 = *approximata*; 23 = *rupestris*.

THE RELATION BETWEEN THE LENTICELS AND ADVENTITIOUS ROOTS OF SOLANUM DULCAMARA. By JAMES A. TERRAS, B.Sc., Lecturer on Botany, Edinburgh. (With Plates.)

(Read 11th January 1900.)

The existence of a definite relationship between adventitious roots and lenticels was recognised for the first time in 1826 by De Candolle (3), as the result of an investigation into the modes of rooting exhibited by a number of cuttings taken from the most varied species of woody plants; and subsequent authors, though differing widely as regards the degree of interdependence of these structures and the functional causes which underlie the connection between them, have never denied the primary fact that the great majority of those lateral adventitious roots, which under favourable conditions are found growing out from the surface of many woody stems, take their origin below lenticels.

Stahl (7), in his classical work on the development and anatomy of lenticels, cited *Solanum Dulcamara* as a species in which nearly all the adventitious roots arise below lenticels, but attempted no explanation.

Fourteen years later, Beijerinck (2) called attention to the remarkably large number of root rudiments occurring on the stem of this plant, and to the facility for vegetative propagation which it in consequence possesses, but made no reference to the connection between these roots and the lenticels, which, indeed, he scarcely mentions.

Klebahn (4), in 1884, figured a lenticel of *S. Dulcamara*, but made no mention of the subjacent root, and the first connected account of the relationship in which these two

structures stand to one another is to be found in a paper by the same author (5) published in 1891, and containing an account in considerable detail of the anatomical features of the fully formed root rudiment, without, however, touching on the question of its origin or mode of development, while he barely does more than refer to the lenticel, which he regards as raised on a small papilla, the projection of which above the general surface of the stem is accounted for by the growth of the underlying rootlet.

The root itself he correctly describes as exhibiting all the anatomical characters of a typical root of the species, though it remains in a state of arrested development so long as the environment of the stem is normal, and only commences to elongate under the influence of excessive moisture.

A superficial examination of any portion of the mature stem of *S. Dulcamara* will in most cases show the surface to be covered with the small papillæ above mentioned, which on the older and thicker portions often reach a height of 1 or 2 mm., and appear as rounded warty excrescences, with rough, nearly vertical, sides, and flat or slightly pointed apices.

Each papilla is accompanied by one or more small dark-coloured lenticels, placed either close to its base on the surface of the stem, in the angle which it makes with the stem, or even on the sides of the papilla itself, though but rarely on its apex, from which, however, the outer layers of cork are not unfrequently abraded, giving a rough surface, at first sight not unlike a lenticel, but easily distinguishable therefrom by the entire absence of the characteristic complementary cells; and this arrangement of parts, which may be looked upon as typical of the mature papilla, is generally to be found on all stems of more than two years of age.

On stems in their second year of growth the papillæ are in general less sharply limited, and appear as rather low dome-shaped protuberances with a smooth rounded surface, bearing on their flanks a pair of small lenticels. These are somewhat elongated in the direction of the axis, and are usually placed near the base of the protuberance, though their number and relative positions may vary considerably,

as many as three being not uncommon, while, on the other hand, they are frequently reduced to one.

They are generally placed laterally, but may occasionally occupy an oblique position, and may even, though but rarely, be found in the median plane longitudinally above or below the papilla.

On shoots of the current year no papillæ whatever are at first recognisable, and they do not make their appearance till a considerable amount of elongation has taken place and the season is well advanced. Small superficial elevations may then be observed on the stem, at or near the base of the year's growth, and as the shoot increases in age these appear at progressively higher levels, till in late autumn, when growth has completely ceased, they may be found within one or two internodes of the apical bud, while those first formed at the base of the shoot have already assumed the characters of second year's papillæ, and, like them, bear lateral lenticels.

The relative number in which these structures appear varies greatly in different plants, and even in different parts of the same plant, their formation seeming to depend to a considerable extent on the degree of transpiration to which the branches are exposed. Plants inhabiting moist situations, such as the margins of deep ditches, etc., have in general their stems almost entirely covered with papillæ, while individuals living in dry airy positions are, on the other hand, nearly devoid of them. In the case of plants growing in hedges and thickets where the surrounding vegetation supplies a considerable check to air movements and thereby limits transpiration, papillæ are especially abundant on the protected twigs, while those which project above the surrounding herbage, and are thus more exposed, are comparatively free from them. Papillæ are also not unfrequently found in larger numbers on the lower than on the upper surface of horizontal branches growing near the ground, and, as Beijerinck (2) has pointed out, wherever a branch of this kind comes in contact with the soil the root rudiments concealed within the papillæ on its lower surface grow out into functional roots.

Although plants growing in dry places never bear so large a number of papillæ as those in moister situations, it

is extremely rare to find an individual from which they are entirely absent, though in some cases they may be reduced to one or two in an internode.

The Stem.—In *S. Dulcamara* the leaves are arranged in a two-fifths spiral, and at each node two vascular bundles unite under the base of the leaf; of these, one arises from the similar vascular union below the leaf two internodes lower down, and the other from that below the next lower leaf, *i.e.* the leaf three internodes below the first, consequently each internode is traversed by five primary vascular bundles, the position of which is indicated on the surface of the young stem by a corresponding number of well-marked ridges.

The primary bundles are, as has been pointed out by De Bary (1), bicollateral in structure, while the internal phloem, itself of considerable thickness, is also accompanied by isolated phloem strands. The bundles are of considerable width in the tangential direction as compared with their rather small radial diameter, and are split up into a number of narrow wedges, each composed of from two to eight radial rows of xylem elements, by a varying number of medullary rays, which extend from the inner limit of the xylem to the outside of the external phloem, without however traversing that on the inner face of the bundle.

These rays are identical in structure with those laid down in the secondary wood, through which they also are continued, both being as a rule but one cell wide tangentially, and from ten to fifteen high, while in both the component cells retain their protoplasmic contents and are rectangular in outline, with the radial diameter about one-third of the height, and somewhat greater than the tangential width.

Under normal conditions the course of such a medullary ray through the phloem till it comes in contact with the inner wall of the pericycle may be readily traced, owing to the regularly radial arrangement of the, in most cases, single row of cells, which, moreover, differ individually, both as regards shape and contents, from the elements of the phloem by which they are bounded on both sides.

Its course within the xylem is equally well defined, but as the walls are now lignified, though thinner than those

of the ordinary xylem elements, it is necessary to depend on the abundant protoplasmic contents of the cells as a means of identification, and, in unstained sections, they are only recognisable with difficulty.

The stem, with its five vascular bundles, is bounded externally by an interrupted circle of isolated sclerenchymatous fibres, of rectangular, roughly square section, and of considerable length, but which in the young state appear to be only partially lignified, as it is in old stems alone that they give any reaction with phloroglucin or aniline sulphate.

These fibres are not limited to the regions immediately external to the primary bundles, but in general occur singly at intervals round the stem, though here and there a group of eight or nine may be found united together by their radial walls, in which case the group generally lies on the outer edge of a bundle. Although occasionally thus united side by side, they are seldom duplicated radially, and when this does occur, both elements clearly result from the division of a single mother-cell.

In longitudinal sections, the outer sieve tubes of the external phloem are readily seen abutting directly on these fibres, which must therefore be looked upon as representing the pericycle, along with the intervening thin-walled cells required to complete the circle, though these latter are in no way specially characterised, and are only distinguishable from those of the succeeding layer by their position and generally smaller size.

In the majority of young stems this fibrous layer is immediately surrounded by a complete circle of rather large cells, especially rich in starch, which is, however, also to be found in the other cells of the cortex, though in somewhat smaller amount, and although the characteristic dot on the radial walls is apparently absent in the stem, there seems no reason to doubt the identity of this layer with the endodermis.

The remainder of the cortical tissue, which generally reaches a thickness of from five to ten cells, is composed of rounded, thin-walled parenchyma, often containing traces of starch, and with large intercellular spaces.

The Root.—The first indication of the appearance of adventitious roots on *S. Dulcamara* takes place at a

comparatively early period, and apparently with remarkable regularity, the initial stages being found only during the formation of the first ring of wood, and in general shortly before or shortly after it has reached half its ultimate thickness, though here considerable variation may occur.

The greater preponderance of root-bearing papillæ, which may frequently be observed on old than on young stems, is probably to be explained by the greater proximity of the former to the surface of the soil, and the consequently greater degree of moisture in the surrounding atmosphere during the period of their development. However this may be, the roots underlying these papillæ may, in the great majority of cases, be traced back without difficulty to within the first ring of wood, even when the stems on which they appear are eight or nine years of age, and one or two centimetres in diameter.

The young roots generally bear a definite relation to the primary vascular bundles of the stem, which, as has been already pointed out, are of considerable tangential width, a point which has here a certain importance, as the roots do not usually arise opposite the median plane, but generally nearer either the right or left hand edge of a bundle, so that papillæ are seldom placed directly on the longitudinal ridges, which in the young stem are the superficial indications of the subjacent bundles, but in most cases on the intervening flat surface.

Though the situation of the root on the circumference of the stem is thus to a certain extent defined, no rule whatever appears to be followed with regard to its longitudinal position, and papillæ seem to arise with equal readiness on the bundle throughout any part of its course.

Van Tieghem and Douliot (8), in their account of the origin of lateral rootlets, state that the adventitious roots which arise from the underground stems of *S. tuberosum* originate in divisions taking place in the single layered pericycle, while the cells of the phlœm parenchyma assist in the formation of the basal part of the central cylinder; and the endodermis forms a digestive cap.

In the species now under investigation, the roots, on the other hand, apparently owe their origin to the proliferation

of the extracambial cells of one or more medullary rays, those implicated being generally situated near one or other margin of the bundle, but still within it, though in rare cases this relation is somewhat difficult to determine, owing to the secondary growth of the stem in thickness. Of these rays, one, two, or as many as three, may be concerned in the formation of a single root, but, where more than one is so employed, the intervening patches of phloem are always very narrow.

When a root is about to arise, those cells of the ray which are situated in the phloem region of the bundle undergo a remarkable series of changes, their nuclei enlarge, they become richer in protoplasm, and at once commence to divide irregularly in all three directions, thus forming a small protuberance with a conical base, which tapers gradually inwards towards the xylem, at the margin of which it is continuous with the internal xylar portion of the ray, and is here of necessity reduced to not more than two cells in tangential width, and in most cases to only one; while the outer rounded apex of the papilla is, on the other hand, composed at this stage of a convex surface, with a perimeter of five or six cells, and generally lies in contact with the inner surface of the pericycle, which is easily recognisable by its fibres. At about this stage, the thin-walled cells of the pericycle, opposite the apex of the papilla, also undergo segmentation, usually dividing, in the first instance, by radial walls, but so irregularly as to render it a matter of great difficulty to determine what part they take in the formation of the root.

Lemaire (7) mentions the occurrence of a somewhat similar irregularity in the initial divisions, which give rise to the adventitious roots of *Tecoma radicans* and *Ficus repens*, both of which further resemble *Solanum* in that their roots arise on the stems in a subaërial position, though, in both cases, all the tissues of the root are formed from the pericycle.

In this connection the behaviour of the pericyclic fibres is of some interest. Though normally the root in its outward course altogether avoids these elements, it not unfrequently happens that a single fibre or small group of

fibres is situated nearly, if not quite, opposite the end of the rhizogenetic medullary ray, and sometimes in direct contact with it.

As the papilla increases in length, these fibres become curved outwards before it; and when, owing to their ends being securely fixed in the tissue above and below, the resistance of the long, tough elements becomes too great to allow of further displacement, they cut into the apex of the root, forming therein a deep, narrow groove, at the bottom of which they may be recognised, though in a somewhat crushed condition, even when the root has reached a stage of comparative maturity.

As the groove so formed extends to the extreme apex of the root rudiment, and cuts through both root cap and periblem, the conclusion seems unavoidable that no cells external to these fibres can have any part in the origin of the root papilla, thus excluding at least the endodermis from all participation in the formation of this structure.

The remaining thin-walled cells of the pericycle undoubtedly divide, but as regards the part which they play in the formation of the root I am at present unable to make any definite statement, though, from a consideration of the arrangement of the cells in median longitudinal sections through somewhat older root rudiments, it seems improbable that they do more than give rise to the root cap, while the cortex appears to arise from the divisions of phloem parenchyma cells on the flanks of the medullary ray, from which the central cylinder takes its origin.

In the younger outgrowths no differentiation into root cap, cortex, and central cylinder is observable, but all three may be distinctly recognised in median longitudinal sections, at a stage so early that no trace of the existence of a root rudiment can be perceived on the surface of the stem. The characteristic dot on the radial walls of the endodermis of the root does not, however, appear till much later, not indeed till the superficial protuberance is almost fully formed and the xylem of the central cylinder is beginning to undergo lignification. It is, however, easily recognisable at the end of the first year in median longitudinal sections which have been double stained in Magdala-red and Malachite-green, the latter of which

colours all lignified and corky elements, while the former is exclusively absorbed by protoplasmic and cellulosic structures.[1]

The Phellogenetic Divisions.—The initial divisions of the phellogen, which in this species arises in the cells of the epidermis, are purely centripetal in direction, and, under normal conditions, the few centrifugal divisions which ultimately occur do not take place till a later period.

The origin of the rootlet, however, considerably precedes the first appearance of phellogen, and the relative rate of growth of these two structures is, in general, such that by the time the root has penetrated to within two or three cells of the outer limit of the primary cortex the phellogen has undergone from one to three centripetal divisions, with the result that the outer persistent portion of the original epidermis is separated from the dividing layer by one or two rows of cork cells.

This relation between the rates of growth of these two almost independent tissues, though fairly constant, is subject, as might be expected, to certain variations. It may, for example, happen that for some reason the origin of the root is somewhat delayed or its growth retarded in comparison with that of the phellogen, as indeed appears to occur normally in the case of the last formed roots of a year's growth.

On the other hand, the elongation of the root rudiment may altogether outstrip the formation of phellogen, a condition which may be readily brought about artificially by placing in water a shoot of the current year, after removal of as much of its basal portion as exhibits well-marked papillæ. When so treated the young root rudiments already formed in the stem increase so rapidly in length as to force their way to the exterior, perforating both cortex and epidermis before even a trace of phellogenetic division has appeared in the latter.

Every stage intermediate between these two extremes

[1] The sections are soaked in a saturated aqueous solution of Malachite-green till deeply stained, and then treated directly with a saturated alcoholic solution of Magdala-red, washed rapidly in absolute alcohol followed by origanum oil and mounted in balsam,—a method of obtaining a double stain for which I am indebted to my friend Dr. Campbell Brown.

may be met with as an occasional variation, probably induced by the action of environmental differences, but under ordinary conditions one or two layers of cork are, as above mentioned, in general laid down before the root reaches to within a distance of two or three cells from the actively dividing phellogen. When, however, this position has been approximately attained, the phellogenetic divisions in the cells immediately opposite the root entirely lose their centripetal character, and there is initiated a series of centrifugal divisions, which, commencing opposite the apex of the root, extend laterally in the phellogen, and eventually result in the formation of a lenticular mass of secondary cortex, with its greatest thickness in the centre opposite the root, but becoming gradually thinner till it disappears in the circumference of a circle, whose diameter is in general about three times that of the root in front of which it originates.

This secondary tissue is entirely composed of thin-walled parenchyma cells, somewhat rectangular in outline, and with but a few small intercellular spaces between their slightly rounded angles.

Considering the relation between the position occupied by the apex of the root, and the period at which the development of this tissue takes place, as well as its exceptional character, it is difficult to avoid the conclusion that its formation must be looked upon as the external evidence of the response made by the actively dividing cells of the phellogen to the pressure exerted on them by the elongation of the root.

The rapidity with which these centrifugal divisions succeed one another in the line of the rootlet's advance is somewhat remarkable, and in general exceeds that of the normal centripetal divisions, taking place at the same time in the unaffected portions of the phellogen. Indeed, the time required for the completion of the whole lenticular mass of tissue, which in its centre often reaches a thickness of twelve or thirteen cells, is frequently less than that occupied by the deposition of a single layer of cork.

This rapid localised deposition of secondary cortex by the phellogen is the primary cause of the formation of protuberances on the surface of the stem, and these, at

least during the earlier portion of the first year, owe almost their entire elevation to it, as the comparatively slow elongation of the root confines it for a considerable period within the primary cortex, where it can exert but little direct influence on the height of the protuberance above it. Later in the season, however, it begins to press heavily on the internal surface of the secondary cortical tissue, and soon penetrates into it, pushing before it the upper and outer layers, and thus greatly increases the elevation of the papilla.

The centrifugal divisions of the phellogen continue even after the apex of the root has pierced the inner layers of the lenticular mass of tissue, but at this period the rate of elongation of the root generally exceeds to a considerable extent that of the formation of secondary cortex, with the result that the former gradually penetrates deeper and deeper into the latter, and, in the majority of cases, entirely pierces it before the end of the second year, though instances are not wanting in which some layers of secondary cortex are still recognisable between the apex of the root and the cork cells covering the outer end of the papilla, as late as the end of the fourth year, so that the root, it would appear, may stop short of reaching the phellogen. This, however, is not of common occurrence; and in most cases when the papilla is fully mature, the root apex may be seen to be covered only by a few cells of cork, or even, owing to the abrasion of the cork layers, to be entirely without protection.

The Lenticels.—Towards the end of the first year one or two typical lenticels appear, as above mentioned, on the lateral flanks of the superficial protuberances.

These arise generally to right and left of the root apex, and apparently owe their origin to a return to the centripetal mode of division taking place in certain circumscribed patches of the phellogen, which, however, instead of laying down ordinary cork tissue proceed to deposit the loose, rounded complementary cells so characteristic of lenticels. As the remaining portions of the phellogen covering the protuberance continue to divide in a centrifugal direction, the lenticellar areas become depressed below the rest of the dividing layer, while their rapid formation of comple-

mentary cells ruptures the layers of cork above them, and thus opens the lenticel to the atmosphere.

The structures so formed persist apparently throughout the life of the plant, and can almost, without exception, even in stems of eight or nine years of age, be found at or near the bases of the papillæ, to which, indeed, they are confined.

CONCLUSIONS.

I. That in *Solanum Dulcamara* the adventitious roots do not arise below or grow out through lenticels, as is apparently the case in the majority of plants.

II. That, as the origin of the root precedes the appearance of phellogenetic divisions, it is entirely independent of lenticellar formation.

III. That the protuberances on the surface of the stem are not lenticels, but result from the formation of a mass of secondary tissue, which originates in the reaction of the phellogen to the pressure set up by the elongating root below it.

IV. That the lenticels only appear after the protuberances are fully formed.

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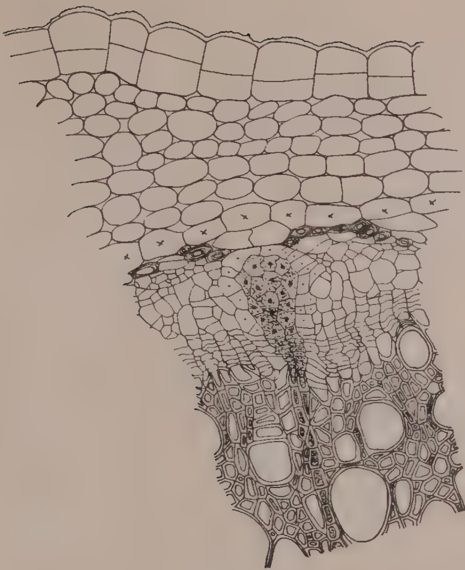
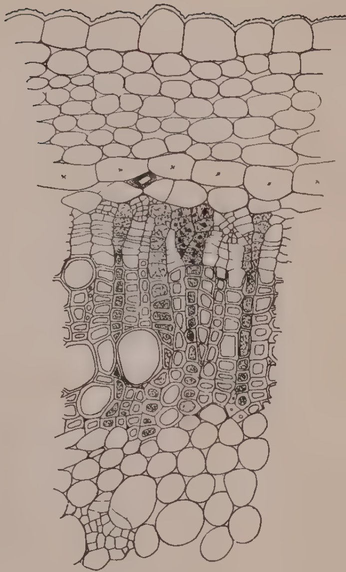


Plate I.



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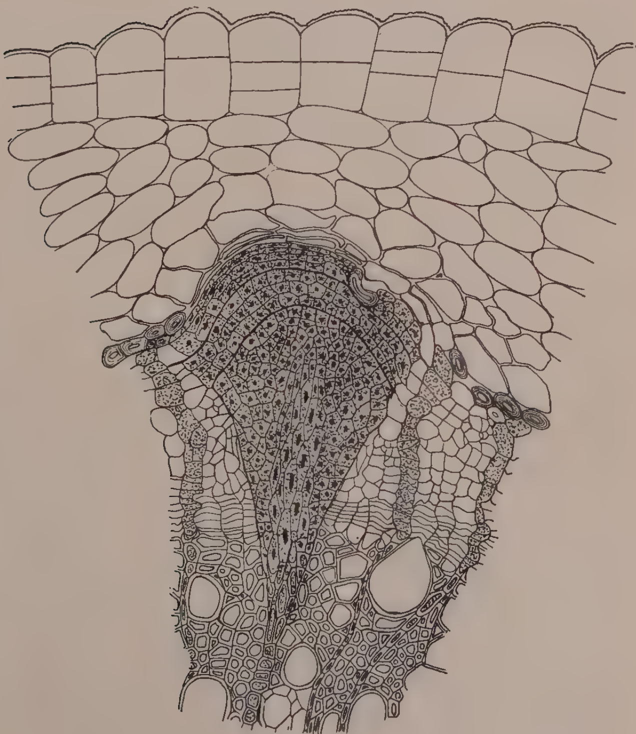

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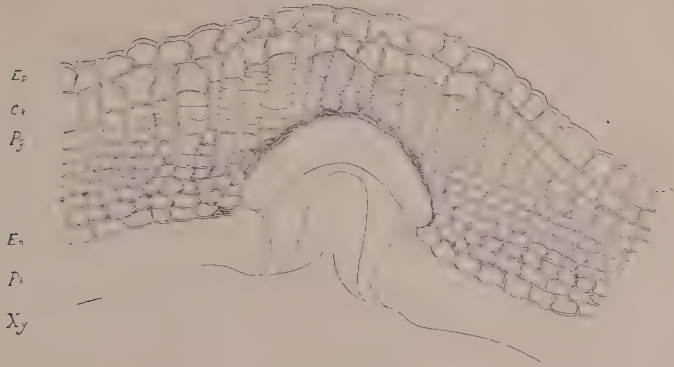

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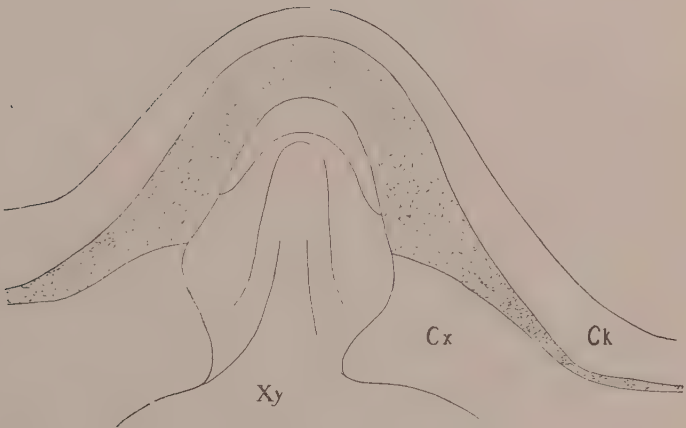

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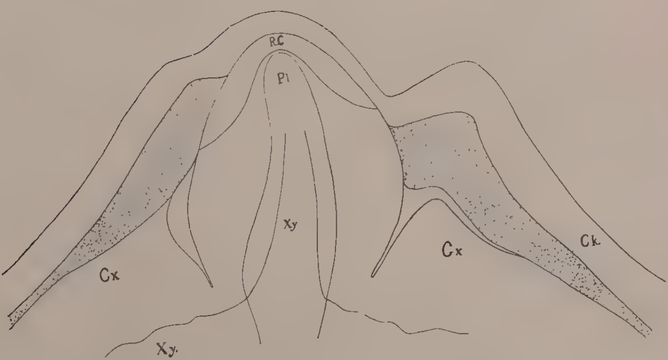

PLATE VI.

EXPLANATION OF FIGURES.

PLATE I.

Fig. 1. Early stage of root, the outer cells of the medullary ray dividing. The cells marked × are endodermal.

Fig. 2. Later stage endodermis as before. Numerous pericyclic fibres; thin-walled pericycle cell opposite root apex, dividing radially; marked cells outside medullary ray tissue represent cells of the phloem region which have become meristematic.

Fig. 3. Root showing three regions. Pericyclic fibre commencing to cut a groove in the apex; endodermis not recognisable owing to growth in thickness of stem.

PLATE II.

Fig. 1. Formation of lenticular mass of secondary cortex opposite apex of root, which has already penetrated its base—*ep*, epidermis; *ck*, cork; *pg*, phellogen; *en*, probable position of endodermis; *ph*, phloem of stem; *xy*, wood of stem.

Fig. 2. Older stage of root. Mass of secondary cortex dotted and partially perforated by the root.

Fig. 3. Mature papilla. Secondary cortex entirely pierced. Root in resting state.

CONTRIBUTIONS TO THE FLORA OF SPITSBERGEN, ESPECIALLY OF RED BAY, from the Collections of W. S. BRUCE, F.R.S.G.S., Naturalist to the Prince of Monaco's Expeditions of 1898 and 1899. By R. TURNBULL, B.Sc., Lecturer on Botany, School of Medicine, Edinburgh.

(Read 8th March 1900.)

In a former communication (9th February 1899) to this Society, I gave an account of the flora of Hope Island, and mentioned Mr. Bruce's first visit to Spitsbergen in the Prince of Monaco's steel yacht, the "Princesse Alice," in 1898. Since the publication of that paper, I have learned that Mr. Leigh Smith collected plants from Spitsbergen and Hope Island, and a record of them is contained in the "Journal of Botany," vol. xiv., 1876.

Some of the plants in the present collection were gathered by Mr. Bruce in 1898, but most of them were obtained during the second voyage of the "Princesse Alice" to Spitsbergen, in 1899.

An account of the two voyages, and a map of Spits-

bergen, are contained in "The Scottish Geographical Magazine" for September 1900.

There are five localities from which plants were collected. Changing Point is the extreme west of Barentz Island, at the head of Stor Fiord, lat. 78° 30′. Recherche Bay and Van Mijen's Bay are branches of Bell Sound, which lies between the 77th and 78th parallels of latitude, to the south-west of West Spitsbergen. Advent Bay is a branch of Ice Fiord, north of the 78th parallel. Red Bay lies exposed to the north, and forms an inlet in the northern coast of West Spitsbergen; it was surveyed for the first time by the Prince of Monaco, and although the Swedes claim to have discovered it, there is no previous record of plants from that region. The position of Bruce Point in Red Bay is 79° 45′ 22″ N. lat., 12° 15′ 28″ E. long., so that the collection from the Bay was made not far south of the 80th parallel.

Mr. Bruce's collection contains about fifty species, which form a fair collection when we consider that his time was avowedly given up to zoology; while his visits to different points were of comparatively short duration.

I have mounted the clumps or tufts unbroken, so as to convey an idea of the true habit of so many Arctic plants.

Out of eight species of Ranunculaceæ known to Spitsbergen, three are in the present collection, viz.:—*Ranunculus nivalis*, *R. pygmæus*, and *R. sulphureus*. *R. nivalis* is one of the common Arctic plants. *R. sulphureus* is represented by a magnificent tuft about nine inches in height. Torell, speaking of this plant (Norwegian Expedition to Spitsbergen in 1861), said that its golden yellow flowers came up to the wanderer's knees.

Papaver nudicaule is abundant, and seems to occur wherever Arctic explorers have penetrated, and it is among the most beautiful of the Arctic plants. Colonel Fielden says of it: "Of the entire flora in the Polar and Arctic regions, no flower is dearer to the explorer than the Arctic poppy. Its beauty, its delightful shades of colour, from white to bright yellow and delicate pink, charm the eye. Its abundance and vitality under apparently the most adverse circumstances make a deep impression.

On the bleakest and most exposed surfaces, as far as the explorer has reached on land, this remarkable flower has been met with. Cold, snow, and tempest seem to make no impression on it."

It is the only representative of its order, but it makes up for the absence of its relatives by the abundance of its individuals. This gives the keynote to the fauna and flora of the Arctic Regions: the species are few, but the individuals abundant.

The order Cruciferæ is represented by eighteen species in Spitsbergen, and the present collection includes five of these. It is well for the Arctic explorer to know that no species of Cruciferæ possesses poisonous properties, and that many of them make excellent salads, chief among these are the species of *Cochlearia*, which were much used by Mr. Bruce and his fellow-travellers.

Of the other species of Cruciferæ the *Drabas* are perhaps the most attractive.

The Caryophyllaceæ are represented by four species. and the most widely distributed of these is the *Cerastium alpinum*, which seems to exist wherever the Poppy is found.

Alpine botanists will also welcome the lowly *Silene acaulis*, which is all but as widely distributed as the *Cerastium*.

Stellaria humifusa is also very common. *Lychnis apetala* is rarer than the other three, but common enough in Novaya Zemlya, it is the *Melandryum apetalum*, L., *Fzl.* of Von Heuglin's list.

The two representatives of Rosaceæ in the present collection are *Dryas octopetala* and *Potentilla fragiformis*: the former is equally common in the Arctic with the Poppy and *Cerastium*, the latter is also common.

The order Saxifragaceæ has eleven species in Spitsbergen, and Mr. Bruce collected nine of these, the commonest and most striking being *Saxifraga oppositifolia*, *S. Hirculus*, and *S. cæspitosa*.

Pedicularis hirsuta is the only representative of Scrophulariaceæ in Spitsbergen, and it is found in the present collection.

Of six Compositæ the only one here is *Erigeron uniflorus*.

Cassiope tetragona is the only representative of Ericaceæ before us, although another *Cassiope* and a *Rhodendron* are also found.

Of three species of Polygonaceæ two are here represented —*Oxyria digyna,* which was found invaluable as a salad, rivalling that of the *Cochlearia*, and *Polygonum viviparum* ; both of these plants are common throughout the Arctic as they are in our own Alpine flora.

Salix polaris represents the Salicineæ, but *S. reticulata* and *S. herbacea* are also found.

Von Heuglin mentions only three species of Juncaceæ. The present collection contains *Luzula hyperborea, Juncus biglumis,* and *J. triglumis,* but there are at least other two which await identification, and which may be new to Spitsbergen. [At the meeting a discussion arose as to whether certain specimens were *Juncus biglumis* or *J. triglumis.* From a careful examination of the specimens, and by comparison with type examples in the Herbarium of the Royal Botanic Garden, Edinburgh, it has been found that both *biglumis* and *triglumis* are in the collection.]

There are eleven species of Cyperaceæ in Spitsbergen, but *Eriophorum vaginatum* is the only representative of the order here.

Out of twenty-six Grasses known the present collection includes nine, and the three rarest are *Trisetum subspicatum*, *Phippsia algida*, and *Poa Vahliana.*

The following is the Phanerogamic Flora of Spitsbergen, as represented in Mr. Bruce's collection :—

A = Advent Bay ; *C* = Changing Point, Stor Fiord ; *B* = Red Bay ; *R* = Recherche Bay, Bell Sound ; *V* = Van Mijen's Bay, Bell Sound.

ORDER—RANUNCULACEÆ.

1. Ranunculus nivalis, L.—*C.*
2. —— pygmæus, Whlnb. —*B.*
3. —— sulphureus, Sol.—*B.*

ORDER—PAPAVERACEÆ.

4. Papaver nudicaule, L.—*C, B.*

ORDER—CRUCIFERÆ.

5. Cochlearia fenestrata, R.Br.—*C.*
6. Draba alpina, L.—*C, B, R.*
7. —— hirta, L. (?)—*C.*
8. —— (?)—*C.*
9. Cardamine bellidifolia, L.—*B.*

ORDER—CARYOPHYLLACEÆ.

10. Cerastium alpinum, L. —*A, B, R, V.*
11. Silene acaulis, L.—*B, R.*
12. Stellaria humifusa, Rottb.—*C.*
13. Lychnis apetala, L.—*A.*

ORDER—ROSACEÆ.

14. Dryas octopetala, L.—*B, R.*
15. Potentilla fragiformis, Willd. —*C, B.*

ORDER—SAXIFRAGACEÆ.

16. Saxifraga cæspitosa, L.—*R.*
17. —— —— var. decipiens, Ehrh. —*C, B, R.*
18. —— cernua, L.—*C, B.*
19. —— flagellaris, Willd.—*C.*
20. —— hieracifolia, Waldst. et Kit. —*C, B.*
21. —— Hirculus, L.—*C.*
22. —— stellaris, L., var. comosa, Poir.—*C, R.*
23. —— oppositifolia, L.—*C, B, R.*
24. —— aizoides, L.—*R.*
25. —— rivularis, L.—*B.*

ORDER—ERICACEÆ.

26. Cassiope tetragona, L.—*A.*

ORDER—SCROPHULARIACEÆ.

27. Pedicularis hirsuta, L.—*C, B.*

ORDER—COMPOSITÆ.

28. Erigeron uniflorus, L.—*V.*

ORDER—POLYGONACEÆ.

29. Polygonum viviparum, L. —*C, R, V.*
30. Oxyria digyna, Hin.—*A, B, V.*

ORDER—SALICINEÆ.

31. Salix polaris, Wahl.—*B.*

ORDER—JUNCACEÆ.

32. Luzula hyperborea, R.Br.—*B, C.*
33. —— (?)—*B.*
34. —— (?)—*V.*
35. Juncus biglumis, L.—*C.*
36. —— triglumis, L.—*R.*

ORDER—GRAMINEÆ.

37. Poa alpina, L.—*A, V.*
38. —— —— L., var. vivipara—*R.*
39. —— flexuosa, Wahl., var. abbreviata, Malmgr.—*R.*
40. Festuca rubra, L., var. arenaria, Osb.
41. —— pratensis, Huds., var. vivipara.—*R.*
42. Trisetum subspicatum, Beauv. —*A, V.*
43. Alopecurus alpinus, Sm. —*A, C, R.*
44. Phippsia algida, R.Br.—*C, B.*
45. Poa Vahliana, Liebm.—*B.*

ORDER—CYPERACEÆ.

46. Eriophorum vaginatum, L.—*A.*

APPENDIX.

THE BOTANICAL SOCIETY OF EDINBURGH.

Founded 1836.

I.—GENERAL VIEWS AND OBJECTS OF THE SOCIETY.

The attention of the Society is turned to the whole range of Botanical Science, together with such parts of other branches of Natural History as are more immediately connected with it. These objects are cultivated :—

1. By holding Meetings for the interchange of botanical information,—for the reading of original papers or translations, abstracts or reviews of botanical works, regarding any branch of botanical knowledge, practical, physiological, geographical, and palæontological,—and the application of such knowledge to Agriculture and the Arts.

2. By publishing annually *Proceedings and Transactions*, including a List of Members and Donations.

3. By the formation in Edinburgh of an Herbarium of Foreign and British Plants, and of a Library and Museum for general consultation and reference.

4. By printing from time to time Catalogues of Plants, with the view of facilitating the study of their geographical distribution, and furthering the principle of exchange.

5. By making Botanical Excursions both in the neighbourhood of Edinburgh and to distant parts of Britain.

6. By appointing Local Secretaries, from amongst the Members of the Society, from whom, in their respective districts, all information regarding the Society's objects and proceedings may be obtained.

II.—LAWS OF THE SOCIETY.

Chapter I.—Fundamental Laws.

1. The Society shall be denominated "The Botanical Society of Edinburgh."

2. The object of the Society shall be the advancement of Botanical Science, by means of periodical meetings, publications, correspondence, and interchange of specimens amongst its Members.

3. The Society shall be open to Ladies and Gentlemen, and shall consist of Honorary, Resident, Non-Resident, and Corresponding Member, who shall have the privilege of denominating themselves Fellows of the Society; of Lady Members elected under the rule Chapter IV., Section 6 hereof, and of Associates elected under the rule Chapter IV., Section 5 hereof.

Chapter II.—Ordinary Meetings.

1. A Meeting of the Society shall be held on the second Thursday of every month, from November to July inclusively.

2. Intimation of all papers to be brought before the Society must be given to the Secretary and submitted to the Council ten days at least previous to the Meeting at which they are to be read.

3. Any Member may transmit to the Society Papers and Communications, which, if approved of by the Council may be read by the author, or, in his absence, by the President or Secretary at any of the Ordinary Meetings.

4. The following order of business shall be observed :—

PRIVATE BUSINESS.

1. Chair taken.
2. Minutes of Private Business of preceding Meeting read.
3. Report of Council read.
4. Applications for Admission read.
5. Members proposed at preceding Meeting balloted for.
6. Motions intimated at previous Meetings discussed.
7. New Motions intimated.
8. Miscellaneous Business.
9. Society adjourned.

PUBLIC BUSINESS.

1. Chair taken.
2. Laws signed by New Members.
3. Minutes of Public Business of preceding Meeting read.
4. Papers and Communications for next Meeting announced.
5. Specimens, Books, etc., presented.
6. Communications and Papers read.
7. Society adjourned.

Chapter III.—Extraordinary Meetings.

An Extraordinary Meeting of the Society may be called at any time, by authority of the Council, on the requisition of three or more Resident Fellows.

Chapter IV.—Admission of Members.

SECTION I.—HONORARY FELLOWS.

1. The Honorary Fellows shall be limited to six British and twenty-five Foreign,—by British, being understood British subjects, whether resident in the British Islands or not.

2. The Council shall have the privilege of proposing Honorary Fellows,—the names of the gentlemen proposed being always stated in the Billet calling the Meeting at which they are to be balloted for. The election to be determined by a majority of at least two-thirds of the votes, provided fifteen Fellows are present and vote.

3. Any Fellow may submit to the Council the names of individuals whom he would wish proposed as Honorary Fellows; and should the Council decline to bring these forward, he may demand that they be balloted for.

4. Honorary Fellows shall be entitled to all the privileges of Resident Fellows, and shall receive copies of the *Transactions* free of charge.

SECTION II.—RESIDENT FELLOWS.

1. A candidate for admission into the Society, as a Resident Fellow, must present an application, with a recommendation annexed, signed by at least two Resident Fellows. The application shall be read at the proper time during private business, and at the next Ordinary Meeting shall be determined by a majority of at least two-thirds of the votes, provided fifteen Fellows are present and vote.

2. Resident Fellows shall, on admission, sign the Laws, and pay the sum of Fifteen Shillings to the funds of the Society; and shall contribute Fifteen Shillings annually thereafter at the November Meeting. Resident Fellows are entitled to receive the *Transactions* provided their subscriptions are paid.

3. Resident Fellows may at any time compound for their annual contributions by payment of Six Guineas. They shall be entitled to receive the *Transactions* yearly as published.

4. Resident Fellows leaving Edinburgh may be enrolled as Non-Resident Fellows, if they have paid by annual subscriptions the sum of Six Guineas, and have also paid any arrears due at their departure. By a further payment of Two Guineas they shall be entitled to receive the *Transactions*.

5. Fellows who are not in arrear in their subscriptions, and in their payments for the *Transactions*, will receive copies of the latter provided they apply for them within two years after publication. Fellows not resident in Edinburgh must apply for their copies either personally, or by an authorized agent, to the Secretary or Treasurer.

6. The Society shall from time to time adopt such measures regarding Fellows in arrears as shall be deemed necessary.

SECTION III.—NON-RESIDENT FELLOWS.

1. Any person not residing in Edinburgh may be balloted for as a Non-Resident Fellow, on being recommended by two Fellows of the Society, and paying a contribution of Three Guineas. From such no annual payment is required.

2. Non-Resident Fellows, by payment of Two Guineas

additional, shall be entitled to receive the *Transactions* yearly as published.

3. Non-Resident Fellows wishing to become Resident, must intimate their intention to the Secretary, who shall put them on the Resident list. They shall pay the annual subscriptions of Fifteen Shillings, or Three additional Guineas, or One Guinea if they have compounded for the *Transactions*.

4. Non-Resident Fellows must arrange with the Assistant-Secretary for the transmission of their copies of the *Transactions*; and they are requested to acknowledge receipt. Billets of the Meetings may, if desired, be also obtained.

5. Non-Resident Fellows coming to Edinburgh shall, for a period of two months, be entitled to attend the Meetings of the Society, and participate in the other privileges of Resident Fellows; after which, should they remain longer, they must pay the usual annual subscription of Resident Fellows, unless they have compounded by payment of Six Guineas.

SECTION IV.—CORRESPONDING MEMBERS.

1. Any person residing abroad may be balloted for as a Corresponding Member, on the recommendation of the Council.

SECTION V.—ASSOCIATES.

1. The Society shall have power to elect by ballot, on the recommendation of the Council, Associates from those who, declining to become Resident or Non-Resident Members, may have acquired a claim on the Society by transmitting specimens or botanical communications. Associates have no vote in elections or in the transaction of the business of the Society, are not entitled to receive copies of the *Transactions*, and have no interest in the property of the Society.

SECTION VI.—LADY MEMBERS.

1. Any Lady, whether Resident or Non-Resident, may become, on the recommendation of the Council, a Member for life on payment of a single contribution of Two Guineas, or may be elected and continue a Member on payment annually of a subscription of Ten Shillings; but Lady Members elected under this rule shall not be entitled to receive copies of the *Transactions*, shall have no voice in the management of the Society, nor any interest in the property thereof.

Note.—Diplomas may be procured by Fellows from the Acting Secretary, the sum payable being Five Shillings, and Two Shillings for a tin case. But no Fellow shall be entitled to receive a Diploma until his contributions have amounted to Three Guineas.

Chapter V.—Office-Bearers.

1. The Office-Bearers of the Society may be chosen from the Resident or Non-Resident Fellows, and they shall consist of a President, four Vice-Presidents, ten Councillors, an Honorary Secretary, an Assistant Secretary, a Foreign Secretary, and a

Treasurer, who shall be elected annually at the Ordinary Meeting in November. If a Non-Resident Fellow be elected an Office-Bearer, he must become a Resident Fellow, in conformity with Section III., Law 3.

2. The Council shall annually prepare a list of Fellows whom they propose to nominate as Office-Bearers for the ensuing year. This list shall be printed and put into the hands of Fellows along with the Billet of the November Meeting; and Fellows shall vote by putting these lists into the ballot-box, with any alterations they may think proper to make. The lists shall not be signed. Every Fellow present at the Meeting is entitled to vote.

3. All the Office-Bearers may be re-elected, except the two senior Vice-Presidents and the three senior Councillors, who shall not be re-eligible to the same offices till after the interval of one year.

4. These Office-Bearers shall form the Council for the general direction of the affairs of the Society. Three to be a quorum.

5. The Council shall nominate annually an Auditor and an Artist, to be recommended to the Society.

6. The Council shall appoint annually at the December Meeting five of their number, including the President and Honorary Secretary, to superintend the printing of the *Transactions* of the Society.

7. The Council may at any time be called upon by the President, Vice-Presidents, or Secretaries, to meet with them for the transaction of private business.

8. The Council shall hold a Meeting for business on the second Tuesday before each General Meeting.

Chapter VI.—The President and Vice-Presidents.

1. It shall be the duty of the President and Vice-Presidents when in the chair, and of the Chairman in their absence, to conduct the business of the Society according to the order of the business laid down in Chapter II., Law 4, and to attend carefully to the enforcement of the Laws of the Society, and to signing the Minutes. The Chairman shall have a vote and a casting vote.

Chapter VII.—The Secretaries.

1. The Honorary Secretary, with the aid of the Assistant-Secretary, shall give intimation of all General and Committee Meetings, shall Minute their proceedings in Books to be kept for the purpose, and shall conduct all the Society's Correspondence in Britain. He shall also take charge of all Donations of Plants and Books, and shall see them deposited in the Herbarium and Library, in conformity with any arrangements made by the Society with Government.

2. The Foreign Secretary shall have charge of all the Foreign Correspondence.

Note.—Agreeably to an Act of the Town Council of the City of Edinburgh, dated January 8, 1839, the Professor of Botany in the University of Edinburgh is constituted Honorary Curator *ex officio*, with free access to the Society's Collection, whether a Member of the Society or not.

Chapter VIII.—The Treasurer and Auditor.

1. The Treasurer, subject to the inspection of the Council, shall receive and disburse all money belonging to the Society, collecting the money when due, and granting the necessary Receipts. His Accounts shall be audited annually by the Auditor appointed by the Society.

2. It shall be the duty of the Treasurer to place all money belonging to the Society in one of the Chartered Banks of this City, unless the same shall have been ordered by the Society to be otherwise invested; and he shall never keep more than Ten Pounds of the Funds of the Society in his hands at a time. The Bank Account shall be kept in the name of the Society, and all drafts thereon shall be signed by the Treasurer.

3. The Treasurer shall, at the November Meeting, submit a certified Statement of the Receipts and Expenditure of the past year, with the Auditor's Report thereon.

Chapter IX.—Visitors.

Each Fellow shall have the privilege of admitting one Visitor to the Ordinary Meetings of the Society at the close of the private business.

Chapter X.—Additional Law.

In the event of any Member acting in such a way as shall seem to the Fellows of the Society to be detrimental to its interests, the Council may recommend that the name of such Member be deleted from the roll. The recommendation shall be brought before the Society at its first Ordinary Meeting. It shall be finally decided at the immediately succeeding Meeting by ballot. If confirmed by a majority of two-thirds of the votes of at least fifteen Fellows, the name of such person shall be deleted from the roll of membership, and all his privileges connected with the Society shall be forfeited.

Chapter XI.—Making and Altering Laws.

Any motion for the alteration of Existing Laws, or the enactment of new ones, shall lie over till the second Ordinary Meeting, and shall then be determined by a majority of at least two-thirds of the votes, provided fifteen Fellows are present and vote. The motion must be intimated to the Council, and shall be printed in the Billet calling the Meeting at which it is to be brought forward, and also in the Billet of the Meeting at which it is to be discussed.

ROLL

OF

THE BOTANICAL SOCIETY OF EDINBURGH.

Corrected to November 1900.

Patron:

HER MOST GRACIOUS MAJESTY THE QUEEN.

HONORARY FELLOWS.

Date of Election.

April 1863. HIS ROYAL HIGHNESS THE PRINCE OF WALES, K.G., K.T., LL.D., Hon. F.R.S. L. & E.

Dec. 1877. HIS MAJESTY OSCAR II. KING OF SWEDEN.

BRITISH SUBJECTS (LIMITED TO SIX).

Nov. 1896. J. G. BAKER, F.R.S., F.L.S., *late Keeper of the Herbarium, Royal Gardens, Kew*, 3 *Cumberland Road, Kew.*

Nov. 1888. DYER, WILLIAM TURNER THISELTON, M.A., LL.D., C.M.G., C.I.E., F.R.S., *Director, Royal Gardens, Kew.*

Jan. 1866. HOOKER, Sir JOSEPH DALTON, M.D., K.C.S.I., C.B., D.C.L. Oxon., LL.D. Cantab., F.R.S., F.L.S., F.G.S., *The Camp, Sunningdale, Berks.*

Mar. 1895. KING, Sir GEORGE, M.D., C.I.E., LL.D., F.R.S., F.L.S., *c/o Grindlay & Co.*, 4 *Parliament Street, London, S.W.;—Corresponding Member, April* 1878.

Dec. 1882. OLIVER, DANIEL, F.R.S., LL.D., F.L.S., 10 *Kew Gardens Road, Kew;—Non-Resident Fellow, Nov.* 1851.

Nov. 1896. H. MARSHALL WARD, F.R.S., *Professor of Botany, Cambridge.*

FOREIGN (LIMITED TO TWENTY-FIVE).

Jan. 1866. AGARDH, JAKOB GEORG, For. F.L.S., *Emeritus Professor of Botany, Lund.*

Mar. 1895. BORNET, Dr. ED., *Member of the Institute, Paris;—Corresponding Member, June* 1879.

May 1891. CORNU, Dr. MAX, *Director of the Jardins des Plantes, Paris.*

Dec. 1885. DELPINO, Dr. FREDERICO, *Professor of Botany in the University, and Director of the Botanic Garden, Bologna;—Corresponding Fellow, Jan.* 1873.

May 1891. ENGLER, Dr. ADOLF, For. F.L.S., *Professor of Botany in the University, and Director of the Royal Botanic Garden and Museum, Berlin;—Corresponding Fellow, Jan.* 1886.

Dec. 1892. GOEBEL, Dr. K. E., For. F.L.S., *Professor of Botany in the University, and Director of the Botanic Garden, Munich.*

Dec. 1885. GRAND'EURY, F. C., *St. Etienne.*

May 1891. HARTIG, Dr. ROBERT, For. F.L.S., *Professor of Forestry in the University, Munich.*

Date of Election.

Dec. 1885. HILDEBRAND, Dr. F., *Professor of Botany in the University, and Director of the Botanic Garden, Freiburg i. Br.*

Dec. 1877. NYLANDER, Dr. GUILLAUME, For. F.L.S., *Paris;—Corresponding Fellow, Jan.* 1865.

Mar. 1895. PFEFFER, Dr. WILHELM, Geh. Hofrat, *Professor of Botany, and Director of the Royal Botanic Garden, Leipzig;—Corresponding Member, Jan.* 1886.

Mar. 1895. SARGENT, CHARLES S., *Professor of Arboriculture, and Director of the Arboretum, Harvard;—Corresponding Member, March* 1878.

Dec. 1885. SCHWENDENER, Dr. S., For. F.L.S., *Professor of Botany in the University, Berlin.*

Dec. 1892. SOLMS-LAUBACH, GRAF. H. ZU., For. F.L.S., *Professor of Botany in the University, and Director of the Botanic Garden, Strasburg.*

Feb. 1876. STRASBURGER, Dr. EDOUARD, For. F.R.S., For. F.L.S., *Professor of Botany in the University, and Director of the Botanic Garden, Bonn;—Corresponding Fellow, Jan.* 1873.

Dec. 1885. TIEGHEM, PHILLIPE VAN, Membre de l'Institut, For. F.L.S., *Professor of Botany, Paris;—Corresponding Fellow, April* 1877.

Mar. 1895. TREUB, Dr. M., *Professor in the School of Agriculture, and Director of the Botanic Garden, Bruitenzorg;—Corresponding Member, Jan.* 1886.

Mar. 1895. VRIES, Dr. H. DE, *Professor of Physiology in the University, Amsterdam.*

Dec. 1885. WARMING, Dr. EUGENE, For. F.L.S., *Professor of Botany in the University, and Director of the Botanic Garden, Copenhagen.*

RESIDENT AND NON-RESIDENT FELLOWS.

No distinguishing mark is placed before the name of Resident Fellows who contribute annually and receive Publications.

* *Indicates Resident Fellows who have compounded for Annual Contribution and receive Publications.*

† *Indicates Non-Resident Fellows who have compounded for Publications.*

‡ *Indicates Non-Resident Fellows who do not receive Publications.*

Date of Election.

Jan. 1871. *Aitken, A. P., M.A., D.Sc., F.R.S.E., 38 *Garscube Terrace, Murrayfield*—FOREIGN SECRETARY.

Nov. 1884. †Alexander, J., 11 *Alexander Road, Bedford, England.*

June 1875. *Alison, Rev. G., *Kilbarchan, Paisley.*

April 1877. ‡Allan, Francis J., M.D., 1 *Dock Street, London, E.*

June 1852. ‡Anderson, John, M.D., F.L.S., 71 *Harrington Gardens, London, S.W.*

Dec. 1866. *Archibald, John, M.D., C.M., F.R.S.E., F.R.C.S.Ed. *Hazelden, Wimborne Road, Bournemouth.*

Dec. 1850. ‡Armitage, S. H., M.D., 39 *Grosvenor Street, Grosvenor Square, London, W.*

Dec. 1888. †Bailey, Colonel Fred., R.E., 6 *Drummond Place.*

April 1887. Bainbridge, A. F., *Brunstane, Arboretum Road.*

May 1872. *Balfour, I. Bayley, Sc.D., M.D., F.R.S., F.L.S., F.G.S., *Queen's Botanist, Professor of Botany, and Keeper of the Royal Botanic Garden, Inverleith House.*—HONORARY CURATOR.

Dec. 1863. †Barnes, Henry, M.D., F.R.S.E., 6 *Portland Square, Carlisle.*

July 1848. *Bayley, George, W.S., 7 *Randolph Crescent.*

Feb. 1857. *Bell, John M., W.S., *East Morningside House.*

May 1891. *Berwick, Thomas, 56 *North Street, St. Andrews.*

April 1857. ‡Beveridge, James S., L.R.C.P. & S., *Melton Constable, Norfolk.*

Dec. 1879. *Bird, George, *St. Margaret's*, 38 *Inverleith Place.*

June 1850. ‡Birdwood, Sir George, M.D., *India Office.*

July 1870. *Black, James Gow, Sc.D., *Professor of Chemistry, University of Otago, New Zealand.*

May 1888. *Bonnar, William, 8 *Spence Street.*

Jan. 1899. Borthwick, A.W., B.Sc., 11 *West Princes Street, Glasgow.*

Date of Election.

Dec. 1886. *Bower, F. O., M.A., D.Sc., F.R.S., F.L.S., *Professor of Botany, University of Glasgow, 1 St. John's Terrace, Hillhead, Glasgow.*
Jan. 1871. *Boyd, W. B., *of Faldonside, Melrose.*
Feb. 1870. †Bramwell, John M., M.B., C.M., 2 *Henrietta Street, Cavendish Square, London.*
Feb. 1837. ‡Branfoot, J. H., M.D., *West Indies.*
April 1857. †Brown, George H. W., *Victoria, Vancouver Island.*
June 1840. †Brown, Isaac, *Brantholme, Kendal.*
Dec. 1890. Brown, Richard, C.A., 23 *St. Andrew Square.*—TREASURER.
Nov. 1882. †Brown, William, *Earlsmill, Darnaway, Forres.*
Mar. 1850. ‡Brown, William, M.D., *Cape of Good Hope.*
June 1893. Bryden, Mrs. J. M., *Linksfield, Aberlady.*
Dec. 1864. Buchan, Alexander, M.A., LL.D., F.R.S.E., *Sec. Scot. Met. Soc.*, 42 *Heriot Row.*
Dec. 1878. *Buchanan, James, *Oswald House, Oswald Road.*
April 1855. ‡Burnett, Charles John, *Aberdeen.*
Feb. 1882. Caird, Francis M., M.B., C.M., F.R.C.S.Ed., 13 *Charlotte Square.*
Dec. 1858. †Carruthers, William, F.R.S., F.L.S., *Central House, Central Hill, London, S.E.*
Feb. 1848. Christison, Sir Alexander, Bart., M.D., 40 *Moray Place.*
Mar. 1893. Christison, Lady, 40 *Moray Place.*
April 1848. Christison, David, M.D., 20 *Magdala Crescent.*
June 1873. *Clark, T. Bennet, *New Mills House, Balerno.*
Dec. 1854. ‡Clay, Robert H., M.D., 4 *Windsor Villas, Plymouth.*
Dec. 1856. †Cleland, John, M.D., F.R.S., *Professor of Anatomy, University of Glasgow.*
July 1896. Coldstream, Wm., B.A., B.Sc., *c/o Messrs. Coutts & Co.*, 59 *Strand, London;—Non-Resident Member, May* 1861.
April 1850. ‡Collingwood, Cuthbert, M.A., M.B., F.L.S., M.R.C.P., 69 *Great Russell Street, London, W.C.*
Dec. 1868. †Collins, James, *Lamb's Conduit Street, Holborn, London, W.C.*
April 1865. †Cooke, M. C., M.A., LL.D., 53 *Castle Road, Kentish Town, London.*
Mar. 1900. Cowan, Alexander, *Woodslee, Penicuik*
Feb. 1870. †Cowan, Charles W., *Valleyfield, Penicuik.*
Dec. 1860. *Craig, Wm., M.D., C.M., F.R.C.S.Ed., F.R.S.E., 71 *Bruntsfield Place.*
July 1897. *Crawford, F. C., 19 *Royal Terrace.*
Feb. 1874. †Crawford, William Caldwell, 1 *Lockharton Gardens, Slateford.*
Nov. 1881. Croom, J. Halliday, M.D., F.R.C.S.Ed., F.R.C.P.Ed., 25 *Charlotte Square.*
July 1871. *Davies, Arthur E., Ph.D., F.L.S., *Tweed Bank, West Savile Road.*
Feb. 1863. ‡Dawe, Thos. Courts, *St. Thomas, Launceston.*
April 1862. ‡Dawson, John, *Witchhill Cottage, Kinnoul, Perth.*
Dec. 1892. Day, T. Cuthbert, 36 *Hillside Crescent.*
Mar. 1841. ‡Dennistoun, John, *Greenock.*
Jan. 1869. ‡Dickinson, E. H., M.D., M.A., 47 *Rodney Street, Liverpool.*
June 1848. ‡Dobie, W. M., M.D., *Chester.*
Jan. 1894. *Dowell, Mrs. A., 13 *Palmerston Place.*
July 1869. *Drummond, W. P., 49 *Trinity Road.*
Dec. 1859. †Duckworth, Sir Dyce, M.D., 11 *Grafton Street, Piccadilly, London, W.*
June 1851. ‡Duff, Alex. Groves, M.D., *New Zealand.*
Dec. 1865. *Duncanson, J. J. Kirk, M.D., C.M., F.R.S.E., 22 *Drumsheugh Gardens.*
Feb. 1871. ‡Dupuis, Nathan Fellowes, M.A., *Professor of Mathematics, Queen's College, Kingston, Canada.*
Dec. 1869. †Duthie, J. F., B.A., F.L.S., *Director, Botanical Department, Northern India, Saharunpore, N.-W.P., India.*
Nov. 1885. Elliot, G. F. Scott, M.A., B.Sc., F.L.S., *Cedar Hall, Kilmalcolm, N.B.*
Jan. 1883. *Evans, Arthur H., M.A., 9 *Harvey Road, Cambridge.*
Mar. 1890. Ewart, J. Cossar, M.D., F.R.S.E., *Professor of Natural History, University.*
Dec. 1860. †Farquharson, Rev. James, D.D., 47 *Mardale Crescent.*
Dec. 1858. †Fayrer, Sir Joseph, M.D., K.C.S.I., F.R.SS. L. & E., 16 *Devonshire Street, Portland Place, London, W.*

Date of Election.

Feb. 1894. Ferguson, R. C. Munro, M.P., *of Raith and Novar, Kirkcaldy*
April 1887. †Fingland, James, *Thornhill, Dumfries.*
June 1838. Fleming, Andrew, M.D., F.R.S.E., 3 *Napier Road.*
Nov. 1861. †Foggo, R. G., *Kaimes Road, Murrayfield.*
July 1885. Foulis, James, M.D., F.R.C.P.Ed., 34 *Heriot Row.*
July 1860. †Fox, Charles H., M.D., 35 *Heriot Row.*
Feb. 1873. *France, Charles S., *Aberdeen.*
June 1874. Fraser, Rev. James, M.A., D.D., *The Manse, Colvend, Dalbeattie.*
June 1836. ‡Fraser, James A., M.D., *Cape Town.*
July 1872. *Fraser, John, M.D., 19 *Strathearn Road.*
Dec. 1865. †Fraser, John, M.A., M.D., *Chapel Ash, Wolverhampton.*
Dec. 1855. *Fraser, Patrick Neill, *Rockville, Murrayfield.*
Mar. 1862. Fraser, Thomas R., M.D., F.R.S., *Professor of Materia Medica,* 13 *Drumsheugh Gardens.*
April 1848. ‡French, J. B., *Australia.*
Mar. 1871. *Gamble, James Sykes, M.A., F.L.S., *High Field, East Liss, Hants.*
Jan. 1866. *Gayner, Charles, M.D., F.R.S.E., *Oxford.*
Jan. 1881. Geddes, Patrick, F.R.S.E., *Professor of Botany, University College, Dundee,* 14 *Ramsay Gardens.*
May 1874. ‡Geikie, Sir Archibald, LL.D., F.R.SS. L. & E., *Director-General, H.M. Geological Survey,* 4 *Jermyn Street, London.*
Feb. 1895. Gibb, W. Oliphant, 21 *Royal Terrace.*
Jan. 1887. *Gibson, A. H., 5 *Crawfurd Road.*
Jan. 1889. *Grieve, James, *Redbraes Nurseries.*
Dec. 1895. *Grieve, Sommerville, 21 *Queen's Crescent.*
Feb. 1879. *Grieve, Symington, 11 *Lauder Road.*
Feb. 1839. ‡Hamilton, John Buchanan, *of Leny and Bardovie.*
Dec. 1868. Hardie, Thomas, M.D., F.R.C.P.Ed., 10 *John's Place, Leith.*
April 1862. ‡Hay, G. W. R., M.D., *Bombay Army.*
May 1887. Hay, Henry, M.D., 7 *Brandon Street.*
June 1862. †Haynes, Stanley, Lewis, M.D., F.R.S., *Medhurst, Malvern, Worcestershire.*
Dec. 1860. ‡Hector, Sir James, K.C.M.G., M.D., F.R.SS. L. & E., F.L.S., *Wellington, New Zealand.*
Nov. 1894. Hepburn, Sir A. Buchan, Bart., *Smeaton Hepburn, Prestonkirk.*
Dec. 1847. ‡Hewetson, Henry, *West Park House, Falsgrave, Scarborough.*
April 1886. Hill, J. R., *Secretary, Pharmaceutical Society, York Place.*
Dec. 1854. ‡Hill, W. R., M.D., J.P., *Lymington, Hants.*
May 1867. *Hog, Thomas Alex., *of Newliston, Kirkliston.*
Feb. 1878. †Holmes, E. M., F.L.S., F.R.H.S., *Curator of Museum, Phar. Soc. of Great Britain, Ruthven, Sevenoaks, Kent.*
Nov. 1884. †Holt, G. A., 8 *Stonewall Terrace, Cheetham Hill, Manchester.*
Dec. 1863. ‡Hossack, B. H., *Craigiefield, Kirkwall.*
Nov. 1873. ‡Hume, Thomas, M.B., C.M., *Madras.*
Jan. 1860. ‡Hunter, Rev. Robert, M.A., LL.D., F.G.S., *Forest Retreat, Staples Road, Loughton, Essex.*
June 1893. Hunter, Robert James, 24 *Craigmillar Park.*
Jan. 1851. ‡Hutchinson, Robert F., M.D., *Bengal.*
Dec. 1847. ‡Ivory, Francis J., *Australia.*
Feb. 1891. ‡Jamieson, Thomas, *Lecturer on Agriculture, University, Aberdeen.*
May 1877. *Johnston, Henry Halcro, B.Sc., M.D., C.M., F.L.S., *Surgeon-Major, Army Medical Staff, Orphir House, Kirkwall.*
April 1858. ‡Johnston, John Wilson, M.D., F.R.S.E., *Surgeon Lieut.-Colonel, Benmore,* 30 *Bidston Road, Oxton, Cheshire.*
Nov. 1869. ‡Kannemeyer, Daniel R., L.R.C.S.E., *Burghersdrop, Cape Colony.*
Nov. 1877. Kerr, John Graham, *Christ's College, Cambridge.*
Mar. 1841. ‡Kerr, Robert, *Greenock.*
Jan. 1854. ‡Kirk, Sir John, K.C.B., M.D., F.R.S., F.L.S., *late British Consul, Zanzibar, Wavertree, Sevenoaks, Kent.*
Jan. 1874. *Kirk, Robert, M.D., C.M., F.R.C.S. Ed., *Bathgate.*
Feb. 1888. ‡Learmonth, W., *Fleetview, Gatehouse of Fleet.*
Feb. 1878. ‡Lennox, David, M.D., F.C.S., 144 *Nethergate, Dundee.*
April 1883. Lindsay, Robert, *Kaimes Lodge, Murrayfield;—Associate, July* 1879.
Mar. 1874. ‡Lister, The Right Hon. Lord, F.R.SS. L. & E., *late Professor of Clinical Surgery,* 12 *Park Crescent, Portland Place, London, N.W.*

Date of Election.

Jan. 1869. †Livesay, William, M.B., C.M., *Sudbury, Derby.*
June 1889. *Loudon, William, 14 *Belgrave Crescent.*
Feb. 1863. †Lowe, George May, M.D., C.M., F.R.C.P., *Lincoln.*
Dec. 1890. Lowson, J. Melvin, M.A., B.Sc., *University Tutorial College, 32 Red Lion Square, London, W.C.*
Jan. 1855. *Macadam, Stevenson, Ph.D., F.R.S.E., *Surgeon's Hall.*
May 1881. Macadam, Col. W. Ivison, F.C.S., F.I.C., F.R.S.E., *Lecturer on Chemistry, Surgeon's Hall.*
Jan. 1895. Macdougall, R. Stewart, M.A., D.Sc., 13 *Archibald Place.*
Jan. 1881. †Macfarlane, John M., Sc.D., F.R.S.E., *Professor of Botany, University of Philadelphia, U.S.A.*
Feb. 1886. M'Glashen, D., 5 *Corrennie Gardens.*
Feb. 1863. ‡Macgregor, Rev. Patrick, M.A., Ph.D., *Logie-Almond Manse, Perthshire.*
June 1880. *M'Intosh, W. C., M.D., LL.D., F.R.SS. L. & E., F.L.S., *Professor of Natural History, St. Andrews.*
Jan. 1889. Mackenzie, A., *Warriston Nurseries.*
May 1862. ‡Mackenzie, Stephen C., M.D., *Professor of Hygiene, Calcutta.*
April 1880. ‡M'Laren, John, jun., 15 *Mill Street, Perth.*
June 1850. M'Laren, Hon. Lord, 46 *Moray Place.*
Feb. 1882. M'Murtrie, Rev. John, M.A., D.D., 5 *Inverleith Place.*
June 1897. ‡Macvicar, Symers M., *Invermoidart, Acharacle, Fort-William.*
Dec. 1896. Mahalanobis, S. C., B.Sc., *University College, Cardiff.*
Dec. 1872. †Maw, George, F.L.S., F.G.S., *Benthall, Kenley, Surrey.*
Nov. 1849. ‡Melville, A. G., *Emeritus Professor of Nat. Hist., Galway.*
April 1837. ‡Melville, Henry Reed, M.D., *St. Vincent.*
Feb. 1890. *Millar, R. C., C.A., 8 *Broughton Place.*
Mar. 1883. Milne, Alex., 32 *Hanover Street.*
Nov. 1875. *Milne, John Kolbe, *Kevock Tower, Lasswade.*
May 1874. Mitchell, Rev. Dr., *The Manse, Hermitage Place, Leith.*
Jan. 1894. ‡Mooney, Dr. J. J., 236 *Brunswick Street, Manchester.*
Dec. 1888. Morris, Rev. A. B., F.L.S., 18 *Eildon Street.*
Jan. 1899. Morton, Alex., B.Sc., 17 *Lutton Place.*
July 1878. †Muirhead, George, F.R.S.E., *Gordon Estates Office, Fochabers.*
Dec. 1889. ‡Murray, J. Russel, *Port-of-Spain, Trinidad.*
Nov. 1848. ‡Nevins, John Birkbeck, M.D., 32 *Princes Avenue, Liverpool.*
Dec. 1878. *Norman, Commander Francis M., R.N., *Cheviot House, Berwick-on-Tweed.*
May 1873. Ogilvie, William M'Dougall, *Royal Bank, Lochee, Dundee.*
Mar. 1898. Orrock, Miss Robina, 7 *Spence Street.*
Feb. 1863. *Panton, George A., F.R.S.E., 73 *Westfield Road, Edgbaston, Birmingham.*
Mar. 1880. ‡Paton, James, F.L.S., *Industrial Museum, Kelvingrove, Glasgow.*
April 1883. *Paul, Rev. David, M.A., LL.D., *Carridale, Fountainhall Road.*
Nov. 1839. ‡Paul, James, M.D., *Jamaica.*
July 1889. *Paxton, W., *Orchardton, Fountainhall Road.*
Nov. 1840. ‡Perry, William Groves, *Australia.*
Mar. 1874. ‡Pettigrew, J. B., M.D., LL.D., F.R.SS. L. and E., *Professor of Medicine, St. Andrews.*
April 1887. Peyton, Rev. W. W.
Jan. 1838. ‡Pires, D'Albuquerque, Le Chevalier, *Brazil.*
Dec. 1874. ‡Playfair, D. T., M.D., C.M., *Redwood House, Bromley, Kent.*
May 1883. ‡Playfair, Rev. Patrick M., *St. Andrews.*
July 1836. ‡Pollexfen, Rev. John Hutton, M.A., *Middleton Tyas Vicarage, Richmond, Yorkshire.*
April 1877. ‡Porteous, George M., *Firknowe, Juniper Green.*
July 1871. ‡Post, G. E., M.D., *Beyrout.*
Nov. 1873. *Potts, George H., *of Fettes Mount, Lasswade.*
June 1891. †Prain, David, M.D., F.L.S., F.R.S.E., *Royal Botanic Garden, Calcutta.*
Orig. Memb. ‡Prior, R. C. Alexander, M.D., F.L.S., 48 *York Terrace, Regent's Park, London, and Halse House, Taunton.*
June 1893. ‡Pullar, Sir Robert, J.P., F.R.S.E., *Tayside, Perth.*
Dec. 1858. †Ramsbotham, S. H., M.D., *Leeds.*
July 1884. *Rattray, John, M.A., B.Sc., F.R.S.E., *Dunkeld.*
Jan. 1878. Reid, Jas. R., C.M.G., 11 *Magdala Crescent.*
April 1877. ‡Riddell, William R., B.A., B.Sc., 109 *St. George's Street, Toronto, Ontario, Canada.*

Date of Election.	
Dec. 1869.	*Robertson, A. Milne, M.B., C.M., *Gonville House, Roehampton Park, London, S. W.*
Dec. 1890.	Robertson, Robert A., M.A., B.Sc., *Lecturer on Botany, St. Andrews, Rattray, Perthshire.*
June 1898.	Russell, Dr., *Cadham, Markinch.*
Dec. 1864.	†Rylands, Thomas Glazebrook, F.L.S., *Highfields, Thelwall, near Warrington.*
July 1882.	*Sanderson, William, F.R.S.E., *Talbot House, Ferry Road.*
Mar. 1869.	*Scot-Skirving, Robert, *of Camptown, 29 Drummond Place.*
April 1881.	‡Scott, Daniel, *Wood Manager, Darnaway Castle, Forres.*
Dec. 1840.	‡Scott, John, *Greenock.*
Dec. 1887.	Scott, J. S., L.S.A., 69 *Clowes Street, West Gorton, Manchester.*
Dec. 1891.	*Semple, Andrew, M.D., F.R.C.S.Ed., *Deputy Surgeon-General,* 10 *Forres Street.*
May 1836.	‡Shapter, Thomas, M.D., LL.D., *Forrest Row, Sussex.*
Dec. 1869.	‡Shaw, John Edward, M.B., 23 *Caledonian Place, Clifton, Bristol.*
Jan. 1851.	*Sibbald, Sir John, M.D., F.R.S.E., 18 *Great King Street.*
Nov. 1836.	‡Sidney, M. J. F., *Cowpen, Morpeth.*
Feb. 1891.	*Smith, J. Pentland, M.A., B.Sc., 21 *Oakshaw, Paisley.*
Feb. 1886.	†Somerville, Alexander, B.Sc., F.L.S., 4 *Bute Mansions, Hillhead, Glasgow.*
Jan. 1890.	*Somerville, William, Œc.D., B.Sc., F.R.S.E., *Professor of Agriculture, Cambridge.*
July 1853.	‡Southwell, Thomas, F.Z.S., *Earlham Road, Norwich.*
Dec. 1854.	‡Spasshatt, Samuel P., M.D., *Armidale, New South Wales.*
June 1874.	Sprague, Thomas Bond, M.A., LL.D., F.R.S.E., 29 *Buckingham Terrace.*
Nov. 1883.	†Stabler, George, *Levens, Milnthorpe, Westmoreland.*
July 1867.	‡Steel, Gavin, *of Carphin, Lanarkshire.*
Feb. 1841.	‡Steele, Robert, *Greenock.*
Jan. 1837.	‡Stevens, Rev. Charles Abbott, M.A., *Port Slade Vicarage, Shoreham, Sussex.*
Feb. 1871.	‡Stewart, Samuel A., *The Museum, College Square North, Belfast.*
Dec. 1892.	Stewart, Robert, S.S.C., 7 *East Claremont Street.*
July 1884.	Stuart, Charles, M.D., *Chirnside.*
Dec. 1869.	Syme, David, 1 *George IV. Bridge.*
Dec. 1887.	Terras, J. A., B.Sc., 40 *Findhorn Place.*—Assistant Secretary.
April 1846.	†Townsend, F., M.A., F.L.S., *Mem. Bot. Soc. Fr., Honington Hall, Shipston-on-Stour.*
May 1888.	*Trail, J. W. H., M.A., M.D., F.L.S., *Professor of Botany, Aberdeen.*
Dec. 1888.	Turnbull, Robert, B.Sc., *Newton Cottage, Morton Street, Joppa.*
July 1886.	†Waddell, Alexander, *of Palace, Jedburgh.*
Dec. 1893.	Waite, Percival C., 13 *Nile Grove.*
Dec. 1861.	*Walker, Arthur A., *Chislehurst, Putney Common, London, S.W.*
Jan. 1856.	‡Walker, V. E., *Arno's Grove, Southgate, Middlesex.*
July 1884.	Watson, William, M.D., *Waverley House, Slateford.*
May 1885.	‡Webster, A. D., *Holwood Park, Keston, Beckenham.*
Mar. 1893.	†Wilkinson, W. H., F.L.S., F.R.M.S., *Marchmont, Wylde Green, Birmingham.*
Dec. 1890.	*Wilson, John H., D.Sc., F.R.S.E., *Greenside Place, St. Andrews;—Associate, Nov.* 1886.
May 1873.	‡Wright, R. Ramsay, M.A., B.Sc., *Professor of Natural History, University, Toronto.*
May 1863	†Yellowlees, David, M.D., LL.D., *Gartnavel Asylum, Glasgow.*

CORRESPONDING MEMBERS.

Jan. 1878.	Areschoug, Dr. F. W. C., *Professor of Botany in the University, and Director of the Botanic Garden, Lund.*
Jan. 1878.	Ascherson, Dr. P., *Royal Herbarium, Berlin.*
April 1877.	Blytt, Axel, *Professor of Botany in the University, and Conservator of the Botanical Museum, Christiania.*
Dec. 1881.	Bohnensieg, Dr. G. C. W., *Conservator of the Library of the Museum Leyler, Haarlem.*
Dec. 1854.	Brandis, Sir Dietrich, Ph.D., F.L.S., *Ex-Inspector-General of Indian Forests, Professor of Forestry in the University, Bonn.*

Date of Election,

Mar. 1895. Brefeld, Dr. O., *Professor of Botany in the University, and Director of the Botanic Garden, Munster.*
Mar. 1881. Caminhoá, Dr. Joaquim Monterio, *Professor of Botany and Zoology, Rio Janeiro.*
Jan. 1866. Candolle, Casimir de, *Geneva.*
July 1879. Cheeseman, T. F., F.L.S., F.Z.S., *Curator of the Museum, Auckland, New Zealand.*
July 1879. Cleave, Rev. W. O., LL.D., *College House, St. Helier, Jersey.*
May 1865. Clos, Dominique, M.D., Corresp. de l'Institut, *Professor of Botany in the Faculty of Sciences, and Director of the Botanic Garden, Toulouse.*
Dec. 1868. Crépin, François, *Director of the Royal Botanic Garden, Brussels.*
Jan. 1878. Eeden, F. W. Van, *Director of the Colonial Museum, Haarlem.*
Mar. 1895. Elving, Dr. F., *Privat-Docent der Universitat, Helsinfors.*
Feb. 1893. Errera, Leo, *Professor of Botany in the University, Brussels.*
Mar. 1895. Franchet, A., *Attaché à l'Herbier Museum d'Histoire Naturelle, Paris.*
Jan. 1878. Garcke, Dr. A., *Professor of Botany in the University, and First Assistant in the Royal Botanic Museum, Berlin.*
April 1844. Gottsche, Dr. K. M., *Altona, Schleswig-Holstein.*
Mar. 1895. Guignard, L., *Professor of Botany, Paris; President of the Botanical Society of France.*
Jan. 1886. Haberlandt, Dr. G., *Professor of Botany in the University, and Director of the Botanic Garden, Graz.*
Dec. 1887. Hansen, Dr. E. C., *Director of the Physiological Department of the Carlsberg Laboratory, Copenhagen.*
Feb. 1876. Heldreich, Dr. Theodore de, *Director of the Botanic Garden, Athens.*
May 1891. Henry, Augustine, M.D., *Imperial Customs Service, China.*
April 1887. Horne, John, F.L.S., *Ex-Director of the Royal Botanic Garden, Mauritius, Sea Braes, St. Clements, Jersey.*
Jan. 1886. Janczewski, Dr. Ed. Ritter von, *Professor of Plant Anatomy and Physiology in the University, Cracow.*
July 1853. Jolis, Dr. Auguste le, *Cherbourg.*
Mar. 1878. Juranyi, Dr. L., *Professor of Botany in the University, and Director of the Botanic Garden, Buda Pest, Hungary.*
Jan. 1886. Kerner, Dr. Anton J. Ritter von Merilaun, *Professor of Botany in the University, and Director of the Botanic Garden, Vienna.*
Jan. 1886. Leichtlin, Max, *Baden-Baden.*
Jan. 1886. Luerssen, Dr. Ch., *Professor of Botany in the University, and Director of the Botanic Garden, Königsberg.*
Jan. 1873. Millardet, A., *Professor of Botany in the Faculty of Sciences, Bordeaux.*
Jan. 1878. Moore, Charles, F.L.S., *Director of the Botanic Garden, Sydney, New South Wales.*
Jan. 1866. Naudin, Dr. C., For. F.L.S., Membre de l'Institut, *Director of the Laboratory, Villa Thuret, Antibes.*
Jan. 1878. Nyman, Charles Frider, *Stockholm*
Jan. 1878. Oudemans, Dr. C. A. J. A., *Professor of Botany in the University, and Director of the Botanic Garden, Amsterdam.*
Jan. 1872. Phillipi, Dr. R. A., *Professor of Botany in the University of Santiago, Chili.*
Dec. 1868. Radlkofer, Dr. L., *Professor of Botany in the University, Munich.*
Mar. 1881. Rodrigues, Joas Barboza, *Director of the Botanic Garden, Rio Janeiro.*
Dec. 1858. Rostan, Dr. Edouard, *San Germano di Pinerolo, Piedmont.*
Feb. 1876. Sodiro, Luis, *Professor of Botany in the University, Quito, Ecuador.*
Mar. 1895. Stahl, Dr. E., *Professor of Botany in the University, and Director of the Botanic Garden, Jena.*
Nov. 1888. Sully, W. C., *Cape Town.*
Dec. 1870. Suringar, W. F. R., *Professor of Botany, and Director of the Botanic Garden, Leyden.*
May 1876. Terracciano, Dr. Nicolao, *Director of the Royal Gardens, Caserta, near Naples.*
Nov. 1888. Tyson, W., *Forest Department, Cape Town.*
Mar. 1895. Vochting, Dr. H., *Professor of Botany in the University, and Director of the Botanic Garden, Tübingen.*
Dec. 1887. Wildpret, H., *Director of the Botanic Garden, Orotava.*

Date of Election.
Dec. 1870. Willkomm, Dr. Maurice, *Professor of Botany and Director of the Botanic Garden, Prague, Bohemia.*

ASSOCIATES.

Dec. 1861. Bell, William, *New Zealand.*
Mar. 1886. Bennett, A., F.L.S., 107 *High Street, Croydon.*
Mar. 1848. Boyle, David, *Boxhill Post Office, Nunwading, South Bourk, Melbourne.*
Feb. 1876. Campbell, A., 62 *Marchmont Road, Edinburgh.*
Feb. 1871. Evans, William, 18A *Morningside Park.*
Dec. 1885. Greig, James, *Woodville, Dollar.*
April 1847. Laing, J., *Seed Merchant, Foresthill, London.*
Mar. 1886. Landsborough, Rev. D., *Kilmarnock.*
June 1891. M'Andrew, James, *New Galloway, Kirkcudbrightshire.*
Feb. 1890. M'Intosh, Charles, *Dunkeld.*
Dec. 1868. Munro, Robertson, *Glasgow.*
July 1898. Pantling, Mr., *Royal Botanic Garden, Calcutta.*
Dec. 1883. Richardson, Adam D., *Royal Botanic Garden.*
May 1868. Shaw, William, *Gunsgreen, Eyemouth.*

LADY ASSOCIATE.

Nov. 1886. Ormerod, Miss E. A., LL.D., *Dunster Lodge, Isleworth.*

LADY MEMBERS.

June 1893. Aitken, Mrs. A. P., 38 *Garscube Terrace, Murrayfield.*
April 1893. Balfour, Mrs. Bayley, *Inverleith House.*
Jan. 1894. Madden, Miss Elizabeth, 15 *Strathearn Place.*
Jan. 1894. Pearson, Miss C. C., 27 *Royal Terrace.*
June 1893. Sanderson, Mrs. W., *Talbot House, Ferry Road.*

THE SOCIETY EXCHANGES PUBLICATIONS WITH—

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Halifax, . . Department of Agriculture.
Nova Scotian Institute of Natural Science.
Montreal, . . Geological and Natural History Survey of Canada.
Natural History Society.
Toronto, . . Canadian Institute.

COSTA RICA.

San Jose, . . Istituto Nacional.

UNITED STATES.

Ames, Iowa, . Agricultural College.
Auburn, Ala., . Agricultural and Mechanical College.
Austin, Texas, Agricultural and Mechanical College.
Boston, Mass., Society of Natural History.
Massachusetts Horticultural Society.
Cambridge, Mass., Harvard University.
Chicago, Ill., . University of Chicago.

Cincinnati, Iowa,	Society of Natural History.
Colorado Springs, Colo.,	Colorado College.
Davenport, . .	Academy of Natural Sciences.
Ithaca, N.Y., .	Cornell University.
Lancaster, Pa.,	Franklin and Marshall College.
Manhattan, Kansas,	State Agricultural College.
Minneapolis, Minn.,	Geological and Botanical Survey of Minnesota.
Mississippi, .	Agricultural College.
New Brunswick, N.J.,	Agricultural College.
New Haven, Conn.,	Academy of Arts and Sciences.
New York, . .	American Museum of Natural History.
	Columbia College.
	New York Academy of Sciences.
	Torrey Botanical Club.
Philadelphia, .	Academy of Natural Sciences.
	University of Pennsylvania.
Rochester, N.Y.,	Rochester Academy of Sciences.
St. Louis, Missouri,	Botanic Garden.
Sacramento, Calif.,	University of California.
San Francisco, Calif.,	California Academy of Sciences.
Topeka, Kansas,	Academy of Science.
Trenton, N.J.,	Natural History Society.
Washington, .	United States Geological Survey.
	Smithsonian Institution.
	United States Department of Agriculture—Division of Botany; Division of Entomology; Division of Forestry; Division of Microscopy; Division of Pomology; Division of Vegetable Pathology; Office of Experiment Stations.

South America.

Monte Video, .	Museo Nacional de Monte Video.

WEST INDIES.

Jamaica, . .	Botanical Department.
Trinidad, . .	Royal Botanic Garden.

AFRICA.

Cape Colony, .	Botanical Department.
Natal, . . .	Botanic Garden.

ASIA.

Calcutta, . .	Botanic Garden.
Straits Settlements,	Gardens and Forest Department.

AUSTRALASIA.

New South Wales.

Sydney, . . . Botanical Department.
Royal Society of New South Wales.

New Zealand.

Wellington, . Colonial Museum and Geological Survey.
New Zealand Institute.

Queensland.

Brisbane, . . Royal Society of Queensland.
Department of Agriculture, Brisbane.

Tasmania.

Hobart, . . . Royal Society of Tasmania.

Victoria.

Melbourne, . . Botanical Department.
Royal Society of Victoria.

EUROPE.

Austria.

Cracow, . . Academia Umiejetnósci.
Graz, . . . Naturwissenschaftlicher Verein für Steiermark.
Vienna, . . . Kaiserlich-Königliches Naturhistorisches Hofmuseum.
Kaiserlich-Königliche zoologisch-botanische Gessellschaft.
Naturwissenschaftlicher Verien der Universität.

Belgium.

Brussels, . . Académie Royale des Sciences, des Lettres, et des Beaux-Arts de Belgique.
Federation des Sociétés d'Horticulture de Belgique.
Société Royale de Botanique de Belgique.
Ghent, . . . Editor of *Botanische Jaarboek.*

Denmark.

Copenhagen, . Botaniske Forening.

France.

Amiens, . . . Société Linnéenne du Nord de la France.
Cherbourg, . . Société Nationale des Sciences Naturelles et Mathematiques.
Lille, . . . Institut Colonial de Marseille.
Lyons, . . . Société Botanique.
Marseille, . . Faculté des Sciences de Marseille.
Paris, . . . Société Botanique de France.
Société Linnéenne de Paris.
Toulouse, . . Société Française de Botanique.

Germany.

Berlin, . . . Botanischer Verein für die Provinz Brandenburg und die angrenzenden Länder.
Bonn, . . . Naturhistorischer Verein der preussischen Rheinlande, Westfalens, und der Regierung-Bezirks Osnabruck.
Niederrheinische Gesellschaft für Natur-und Heilkunde.

Braunschweig, . Verein für Naturwissenschaft.
Bremen, . . . Naturwissenschaftlicher Verein.
Breslau, . . . Schlesische Gesellschaft für vaterlandische Cultur.
Erlangen, . . Physikalisch-medicinische Societät.
Frankfort-am-Oder, Naturwissenschaftlicher Verein des Regierungsbezirks.
Giessen, . . . Oberhessische Gesellschaft für Natur- und Heilkunde.
Halle, . . . Kaiserliche leopoldino-carolinische deutsche Akademie der Naturforscher.
Kiel, ... Naturwissenschaftlicher Verein für Schleswig-Holstein.
Königsberg, . Physikalisch-oekonomische Gesellschaft.
Munich, . . . Baierische Gesellschaft.
Strasburg . . University Library.

GREAT BRITAIN AND IRELAND.

Alnwick, . . Berwickshire Naturalists' Club.
Belfast, . . . Natural History and Philosophical Society.
Belfast Naturalists' Field Club.
Bristol, . . Bristol Naturalists' Society.
Buckhurst Hill, Essex Field Club.
Dublin, . . . Royal Dublin Society.
Dumfries, . . Dumfriesshire and Galloway Natural History and Antiquarian Society.
Edinburgh, . . Royal Scottish Arboricultural Society.
Royal College of Physicians.
Edinburgh Geological Society.
Royal Society of Edinburgh.
Royal Physical Society.
Royal Scottish Geographical Society.
Royal Scottish Society of Arts.
Glasgow, . . Natural History Society.
Philosophical Society.
Hertford, . . Hertfordshire Natural History Society and Field Club.
Leeds, . . . Yorkshire Naturalists' Union.
London, . . . Editor of *Gardeners' Chronicle*.
Linnean Society.
Editor of *Nature*.
Pharmaceutical Society of Great Britain.
Quekett Microscopical Club.
Royal Gardens, Kew.
The Royal Society.
Royal Horticultural Society.
Royal Microscopical Society.
Manchester, . Manchester Literary and Philosophical Society.
Newcastle-upon-Tyne, Natural History Society of Northumberland, Durham, and Newcastle-upon-Tyne, and the Tyneside Naturalists' Field Club.
Norwich, . . Norfolk and Norwich Naturalists' Society.
Perth, . . . Perthshire Society of Natural Science.
Plymouth, . . Plymouth Institution.

HOLLAND.

Amsterdam, . Koninklijke Akademie van Wettenschappen.
Haarlem, . . Musée Teyler.
Nederlandische Maatschappij ter Bevordering van Nijverheid.
Luxembourg, . Société Botanique du Grand-duché de Luxembourg.

ITALY.

Rome, . . . Reale Istituto Botanico.

PORTUGAL.

Lisbon, . . . Academia real das Sciencies.

RUSSIA.

Helsingfors, . Societas pro Fauna et Flora Fennica.
Kieff, . . . Société des Naturalistes.
Moscow, . . Société impériale des Naturalistes.
St. Petersburg, Hortus botanicus imperialis.

SCANDINAVIA.

Lund, . . . Universitas Lundensis.
Stockholm, . . Kongl. Svenska Vetenskaps Akademien.
Sveriges Offentliga Bibliotek.
Upsala, . . . Societas Regia Scientiarum.

SWITZERLAND.

Berne, . . . Naturforschende Gesellschaft.
Geneva, . . . Herbier Boissier.

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OF THE

BOTANICAL SOCIETY OF EDINBURGH